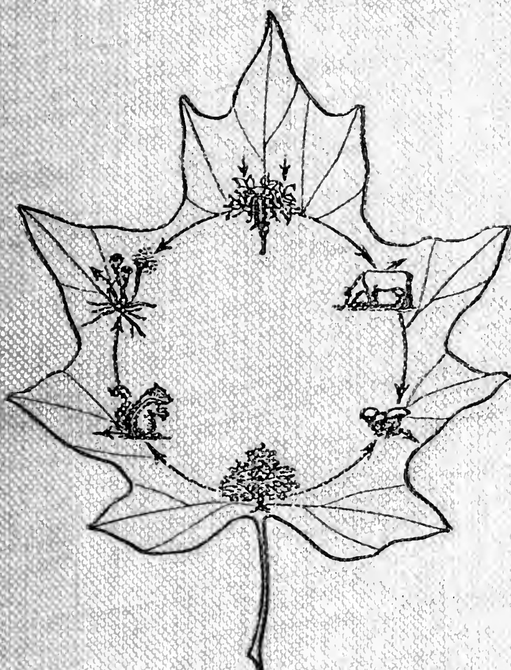
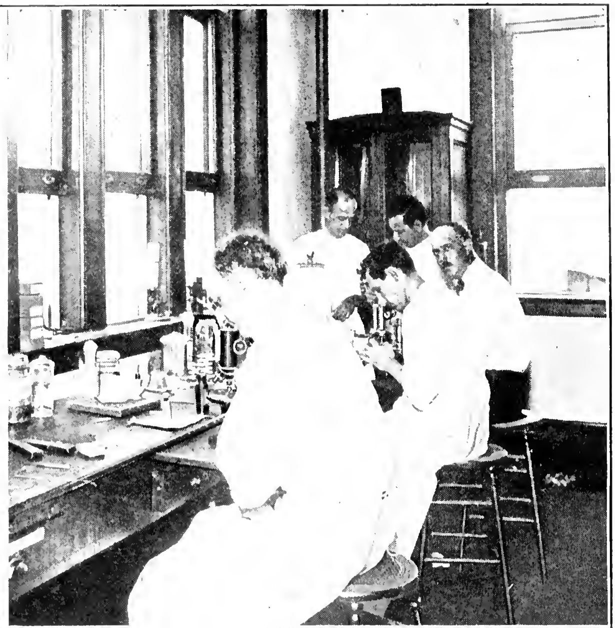
BIOLOGY AND HUMAN LIFE



GRUENBERG



Two ways of dealing with sickness

A Shaman, or medicine man, of the Yukaghir tribe in northern Siberia healing the sick by driving out devils with appropriate noises. In contrast with this, scientists in a laboratory in New Orleans searching for bacteria of plague with the help of microscopes. (Courtesy of the American Museum of Natural History)

BIOLOGY AND HUMAN LIFE

BY

BENJAMIN C. GRUENBERG

FORMERLY HEAD OF THE BIOLOGY DEPARTMENT IN THE JULIA RICHMAN HIGH SCHOOL, NEW YORK

GINN AND COMPANY

BOSTON · NEW YORK · CHICAGO · LONDON
ATLANTA · DALLAS · COLUMBUS · SAN FRANCISCO

225.4

The Athenæum Press
GINN AND COMPANY · PRO-
PRIETORS · BOSTON · U.S.A.

PREFACE

The report of the National Education Association committee on the "Reorganization of Science in Secondary Schools" lays down the principle of a synthetic treatment of biology. In some quarters the change appears to have gone no farther than the substitution of "plant biology" for botany, "animal biology" for zoölogy, and so on. The present book assumes that the tendency toward a unified treatment of more comprehensive principles, which is paralleled in other departments of instruction, represents the most fruitful adjustment of schooling to the rapidly growing body of scientific knowledge.

It takes account further of another tendency in our current life, namely, the rapid extension of secondary-school opportunities to new population groups. The high schools now receive increasing numbers of boys and girls whose interests and aspirations are radically different from those of earlier generations of pupils. The high school is no longer primarily or chiefly a college-preparatory institution. More and more of our students are concerned with the concrete and the practical rather than with the abstract and theoretical. Boys and girls who look forward to an early entrance upon occupational activities and the responsibilities of earning and spending money have as much need for the study of biology as have those who plan to go to college or the professional schools. Even among these last there are very many for whom the subject can be most interestingly and most profitably developed in terms of our everyday affairs rather than in terms of academic analysis.

The division of this book into three main parts ("Getting Acquainted with Life," "Biology of Health," and "Biology of Wealth") is intended to emphasize applications of science to human affairs, and at the same time to suggest that we have to get knowledge before we can apply it. Each chapter is preceded

by a few questions that are designed to represent the pupil's point of view. The questions at the ends of the chapters, together with the outlines and summaries, represent rather the teacher's point of view; they do not call for a mere reproduction of the matter in the text, but are intended to stimulate the pupil to resurvey the subject matter, to reorganize it, and to reorient it for himself. The organization of the text, the questions, and the outlines carry for the teacher implicit suggestions as to what procedure will best furnish the concrete observation, experimentation, demonstration, etc. needed for an understanding of the ideas treated; and for the pupils they carry something more than explicit suggestions as to the meaning of reliable method in the solving of various problems. The reference readings are mostly from materials readily obtained from government agencies.

The text has been carefully checked against Thorndike's word list for ninth-grade pupils. New words that do not have their meanings revealed by the context are defined, and the Index will serve as a pronouncing vocabulary as well as a reference to definitions or explanations. Many of the illustrations are taken from the author's "Elementary Biology," some of them with slight modifications; many, however, have been made especially for this book, and some are for the first time made accessible to high-school teachers and pupils, such as the Ancon type of sheep mutation and the arterial system of the arm as shown by the X rays. Acknowledgment for photographs and other materials is made in connection with the several illustrations, but the author wishes here to express his deep appreciation of the splendid coöperation received from the various scientists and institutions, as well as for the patient efforts of the artists who have assisted in developing many of the special drawings—Mr. F. Schuyler Mathews, Mr. Frank M. Wheat, Miss Marcelle Roigneau, and Mr. Carl A. Schwarze.

B.C.G.

CONTENTS

PART I. GETTING ACQUAINTED WITH LIFE

PART II. THE BIOLOGY OF HEALTH

INTERMEZZO. WHAT EVERYBODY WANTS

KEEPING THE BODY IN CONDITION

THE CONTROL OF THE BODY

INTERMEZZO. MAN'S DEPENDENCE

CONTROL OF THE ENVIRONMENT FOR HEALTH

PART III. THE BIOLOGY OF WEALTH

INTERMEZZO. WEALTH

PRODUCTION

TO THE TEACHER

While the organization of the text is believed to be both logical and pedagogical the teacher will find no difficulty in departing from it as desired; we have long recognized that both in the development of our subject and in the assignment of lessons it is unnecessary to go from page to page through a textbook. Moreover, since it is necessary to base the pupil's study of his textbook upon concrete observations and experiences, the use of the book must be to some extent influenced by the material available from time to time.

The questions preceding the chapters offer suggestions for individual and joint projects of various kinds. Although they often take the form of a challenge to the teacher, we should proceed with our work on the assumption that we and our pupils are equally interested in discovering what is true and important. Where individuals can give us reliable and authoritative answers, the class, including the teacher, should be glad to receive them, although each individual, including the teacher, may reserve the right to ask the informant, "How do you know?" Often we shall find that the best knowledge we have is a more or less workable hypothesis; often we shall find that knowledge is still to be dug out of resistant reality; and at other times we shall find that the questions are not real questions at all, being based on assumptions contrary to fact.

When we come to the questions at the ends of the chapters, we may treat them frankly as teacher's questions. Yet these are all offered without prejudice; that is to say, they are offered without intent to impose any doctrine. Where we ask about the advantage of a process or a procedure, we must be ready to consider also the disadvantage; where we ask, in comparing, for similarities, we must consider also differences; and so on.

Many of the questions assume that the teacher and pupils have actually seen, handled, experimented with, tested, smelled, and taken apart or put together; they can be answered, if at all, only as a result of field or laboratory or museum study. In other cases the replies to questions must be in the form of inferences calling for further testing or verification. There are also suggestions for civic studies in terms of what is actually being done in the community—how we obtain our means of livelihood, how we manage our joint affairs, how we meet our common enemies. It is not to be expected that every pupil will obtain an acceptable answer for every question. On the other hand, many of the questions are of a type that permits endless variation in terms of local conditions or matters of current importance; it may not be sufficient, then, if the pupils can answer only the questions given. At best the questions are to be used as stimuli for thought and investigation.

The outlines, or summaries, at the ends of the chapters, often in combination with the questions, are intended to assist in the organization of ideas. They should show relationships of topics to one another within the subject of the lesson, but they should also suggest relationships between these topics and others previously studied, as well as others not yet touched upon. In other words, while a useful summary or outline must answer questions that arise in the course of the study, it should also raise new questions: there are no periods in these outlines.

Most of the reference readings are to government publications of various kinds. It would be well for each school to obtain from the Superintendent of Documents, Government Printing Office, Washington, D. C., a list of the price lists. From this list the various price lists can be ordered, and from these price lists we can learn what pamphlets and books are available. Every teacher should acquaint himself with the more important types of government publications and with the methods of obtaining them for the school with the least cost or effort. In many cases documents can be obtained with the coöperation of the congressman. Besides the pamphlets in the various price

lists, you should get, through your congressman, the yearbooks of the Department of Agriculture, the annual reports of the Surgeon-General of the Public Health Service, and the annual reports of the Smithsonian Institution. State agricultural experiment stations, state and local boards of health, state and other museums, and the larger insurance companies also issue publications of value to the students of biology. Several of the larger voluntary health organizations have in recent years come to coöperate in some of their administrative problems, and can all be reached at one address—370 Seventh Avenue, New York. Most of the following organizations have available literature of value in the teaching of biology: the American Child Health Association; American Heart Association; American Social Hygiene Association; American Society for the Control of Cancer; National Committee for Mental Hygiene; National Tuberculosis Association; American Association for Medical Progress; American Committee for the Prevention of Blindness. Some of the most helpful material is to be found in current magazines and newspapers, and pupils should be encouraged to find both problems and applications in the current record of the human life about them.

The classification of plants and animals appeals to individuals here and there, but we cannot afford to give it too much time as a branch of biology. Yet it is worth while to indicate briefly both the methods and principles of classification, and the practical uses of careful description and naming. The material in the text, it must be clearly understood, is not something to be learned, but a convenient scheme of reference. Every plant or animal that comes to the attention of the class should be placed within its phylum, or class, or order, as conditions permit; but no attempt should be made to get the pupils to memorize the definitions of the various groupings. With frequent reference to the scheme, however, it is certain that most children will get all they need of taxonomy.

There are no separate chapters on the chemical processes often presented in elementary studies as fundamental to phys-

iology. Many of the high schools offer biology after general science so that this material is frequently no longer necessary. Where the pupils have had no such instruction, however, or where it seems necessary to review, a few simple experiments on oxidation and its products, on acidity and alkalinity, and on the idea of chemical reaction as illustrated by various types (precipitation, effervescence, color change), as well as chemical tests for nutrients, for carbon dioxid, etc., may be introduced early in the course (see Part I of the author's "Manual of Suggestions for Teachers").

Most teachers may prefer to prepare their own instructions to pupils for carrying out experiments, field observations, and other projects, for keeping records of their observations, readings, etc., and for gathering data of various kinds. Where there are large classes, or many of them, it will be economical to use printed manuals for students. In any case the teacher will prepare his own lesson by making up his mind clearly in advance just what he expects the pupils to get out of the lesson and what methods are to be followed for reaching the goal.

BIOLOGY AND HUMAN LIFE

PART I. GETTING ACQUAINTED WITH LIFE

CHAPTER I

WHAT IS BIOLOGY?

Questions. **1.** What does biology mean? **2.** How is biology used? **3.** What makes biology interesting? **4.** How is biology studied? **5.** What is life? **6.** How do living things differ from other things?

1. Definition. The word **biology** is easily defined. It means "life knowledge," or "life teaching," from *bios* (life) and *logos* (the word, or knowledge). But, like many other simple words, it covers a great deal of what people know, as well as much more that they do not know. Many men have spent their lives in trying to find out just what science, or real knowledge, is. Still, we need not be afraid of the subject. Every one of us may reasonably hope to get a considerable amount of reliable and usable and satisfying knowledge concerning life.

2. What is life? Suppose you asked an expert electrician, like Edison or Marconi, "What is electricity?" He would be likely to answer very frankly, "I don't know." Yet everybody knows something about how wonderfully electricity is *controlled* and *used*. So we must say frankly we don't know just what life is, although we have gathered many wonderful and important *facts about life*. These facts we are able to *use* in many ways.

We give the name *life* to all that distinguishes *living things* from those that are not living. Some people think that life is a kind of force, or *energy*; but if it is, it differs in many ways from electricity and other forms of energy. Some people think that life is a kind of *substance*, or fluid; but if it is, it differs in many ways from all the other kinds and states of matter that we know. All we can say is (1) that life is present only in certain objects or bodies (*plants* and *animals*), which contain many different kinds and states of matter; and (2) that in these

bodies life is present only under certain *conditions*, which include electricity, chemical energy, heat, and others. But we cannot think of life by itself. It means nothing to us except the way living things behave—what plants and animals *do*.

3. How biology is used. Many plants and animals have a bearing upon human life. A little reflection will show that whatever we can *do* about living things we can do more

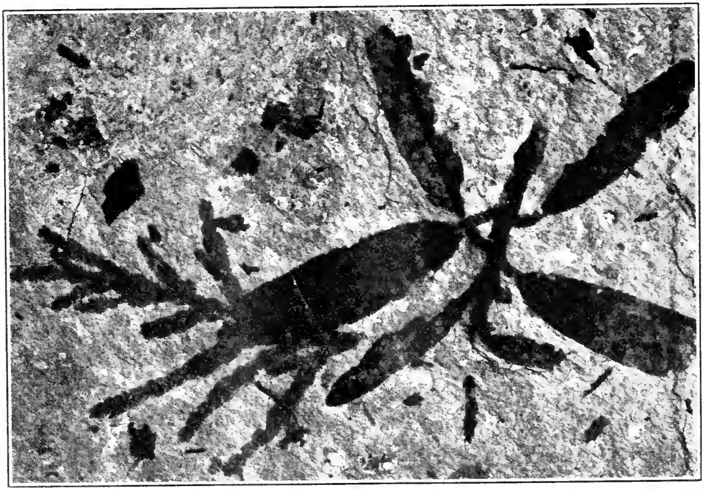


Fig. 1. Fossil remains of plant life

The plants that left these impressions in the rocks at Florissant, on the western side of Pikes Peak in Colorado, lived a million years ago or more. (From photograph furnished by the American Museum of Natural History)

effectively or usefully if we have a better understanding of life. In the case of our useful plants and animals, biology can teach us how to increase their numbers, how to protect them from their enemies or disease, and also how to improve their qualities. In the case of our own bodies, biology teaches us substantially all we know about preserving health and about curing disease. It is applied biology that has made it possible, since the Civil War, to add over ten years to the average length of life of people

living in this country. A knowledge of plants and animals is a constant source of satisfaction when we come in contact with wild or domesticated forms and have a chance to observe their structures and activities "just for fun." The more we learn about life the better able we are to understand ourselves and our fellow beings, and so better able to manage ourselves in many situations. Finally, biology is coming to be used more and more in the management of our common affairs, in town

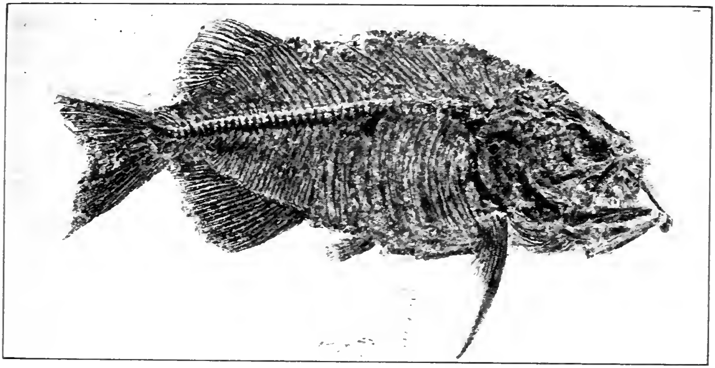


Fig. 2. Fossil remains of animal life

The fish that left this record in the rocks at Twin Creek, Wyoming, lived between two and three million years ago. (From photograph furnished by the American Museum of Natural History)

and city and in the nation at large, in industry, and wherever people have to come together for any purpose. But the greatest value of biology, as of every other study, will be tested by its ability to make life easier to help us get more out of life.

4. What there is to study about living things. Almost from the first, little children want to know the *names* of the different objects that come to their attention, and about the *classes* to which each new acquaintance belongs. One department of biological study concerns itself chiefly with describing and comparing all sorts of plants and animals for the purpose of making complete *classifications*. Here the student wants to

make sure that each kind has its own name, and that a given name stands always and everywhere for the same kind. This work is not only interesting for those who like that sort of thing, but it is also of great value to other workers. It is important to know, for example, when a farmer complains of some insect or mildew injuring his crop, exactly who the enemy is, and not to confuse him, from slight resemblances, with another insect or mildew that may be harmless. Hundreds of situations are constantly arising in which it is important to know to what group a particular individual belongs, or whether a given plant or animal species has ever been described and named before. So exact description, classification, and naming are well worth while.

Another branch of study concerns itself with the *places* upon the earth where each kind of living thing is to be found, or under what conditions it lives. Still another study has to do with the kinds of living things that existed upon the earth in ancient times, as may be learned from the remains in the rocks (*fossils*) and coal beds, or perhaps preserved in the glaciers, or ice fields, of Greenland and Siberia.

Many people concern themselves with the study of *structure* and arrangement of parts in plants or animals. Others, again, are more interested in what living things *do*; and people were interested in that long before there was any systematic science of biology. In modern times more and more attention is being given to questions about *how* living things carry on the various processes and activities that distinguish them from non-living things. How do plants get food? How are moths attracted by light? How does vaccination prevent disease? How do migrating birds find their way? How do seedless plants reproduce? Hundreds of questions are constantly coming to mind.

Many people are chiefly interested in such questions as How came there to be all the different kinds of plants or animals? What makes different kinds resemble each other, for they are not altogether different? What brought about the changes in the inhabitants of Europe or North America during the past

million years or more? What has caused ancient types of plants and animals to disappear? How did existing species originate? How came plants and animals to fit in so beautifully into their particular living conditions?

There are always men and women, boys and girls, who like to ask practical questions about everything that happens. What difference does it make if caterpillars do have biting jaws, or if clover plants have little lumps on their roots? What can we do about it? What should we do about it?

It is impossible for everybody to think of *all* these questions, much less to get the answers to all. The more we find out, the more questions arise. So, more and more, people are choosing just what particular questions or classes of questions they will specialize in. Yet every one of us can learn some of the more important questions in each department, and something about why they are important, without becoming specialists.

5. What makes biology interesting? It is impossible to say beforehand just what will interest a certain person. Some of us go in for postage stamps, while others prefer Chinese puzzles or music. A subject like biology, which covers so much of the world we live in, has in it something of interest for almost everybody. There are several million different kinds of plants and animals; this must interest those who care about collecting, sorting, matching, naming. New species are being discovered, classified, and named every year. Hundreds of men and women are constantly hunting for new varieties. Plants and animals occur under such a great variety of conditions, and show such remarkable variety of structure and habit corresponding to these conditions, that they are a constant source of amazement.

Many remarkable relations are found among the parts of any given plant or animal, as well as among the different plants and animals in a given region. Thus, a slight chemical change in one part of the body may bring about a violent change in the action of the heart or of the nervous system; or the extermination of an insect in one region may have a striking effect upon

the health of human beings or of some species of plant. Many of us get much satisfaction from the beauty of living things; and while *enjoying* the song of a bird or the fragrance of a flower is not quite the same as *studying* biology, there is the possibility of increasing our satisfaction by increasing our knowledge of living things. Indeed, for many boys and girls there is more of a thrill in solving a problem about the *how* of living things than in almost any other kind of experience. Biology may be a great adventure of exploration into a wonderful

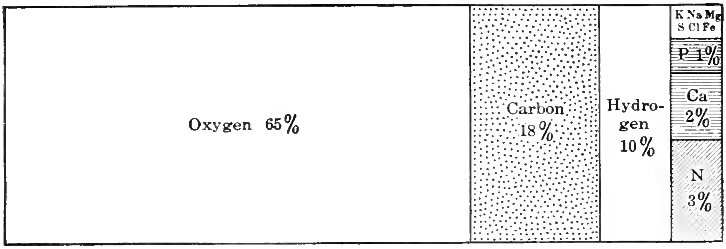


Fig. 3. The chemical composition of the human body

In addition to the elements named there are nitrogen (N), calcium (Ca), phosphorus (P), potassium (K), sodium (Na), magnesium (Mg), sulfur (S), chlorin (Cl), iron (Fe), and traces of iodin, fluorin, and silicon. The same chemical elements are found in other living bodies

world of which the largest part is still unknown. To many people biology is interesting because it answers practical questions about the relations of plants and animals to our business, our health, our sources of timber and furs and other useful material, our laws, and so on.

6. How biology is studied. Everybody knows *some* biology, even without having studied it. Whatever you know about taking care of the baby, or a pet animal, or a garden, or a potted plant, whatever you know about taking care of yourself, is so much practical biology, no matter where or how you learned it. We are constantly picking up a great deal of reliable and useful information, just as we are picking up a great deal of rumor or gossip or superstition that is neither true nor useful. To get

the utmost value from what we finally carry around with us in the way of ideas about plants and animals there should be some systematic study. You might go out and gather up all the samples of plants and animals you come across, and start sorting them. Or you might use a magnifying glass and discover in every sample many things that you would otherwise never have found out. Or you might cut your samples open and find out something about their internal organs, and perhaps guess at what makes them go. Or you might sit still and watch what is going on in the ground, in the water, in the air, and make note of what you see and hear. You might take your samples into the laboratory and test them to find out what kinds of material enter into their composition, or what changes they bring about in the materials they take in. Or you might experiment with them to find out what makes them do the many queer things.

All the methods of classification, observation, and experimentation may be used on all living things. But we do not have to do all these things for every animal and plant. Indeed, we shall find these methods very slow, even if we confine ourselves to the study of only a single kind of life form. We shall have to get a very large part of our knowledge at second hand, by being told what others have found out before us, through conversations, through lectures, through reading, through pictures. Yet, no matter how much we may get out of books, it is well to remember that all useful knowledge *originates* in the observations and experiences and experiments of people like ourselves. Whether we use our naked eyes or have the assistance of microscopes and telescopes, whether we taste and smell bits of plants and animals or make use of chemicals, whether we merely pull a lizard's tail to see what he will do or develop long and complicated experiments, *the source of all biological knowledge is in the plants and animals themselves and not in books.*

7. What living things do. All living things, even plants, are constantly *doing* something that brings about changes in the world. Some of these activities are very rapid, or sudden, or dramatic: a hawk swoops down and carries off a fowl, or an

army of locusts travels across a state and destroys every bit of grass and foliage in its path. Some of these activities are slow or not easily observed. Thus, the coral animals, in the course of centuries, build up an island in the midst of the sea; a growing tree splits a great rock asunder with its expanding roots.

Some plants and animals produce effects that do not last long or reach very far, but others produce effects that reach down through long periods of time or spread over wide regions. For

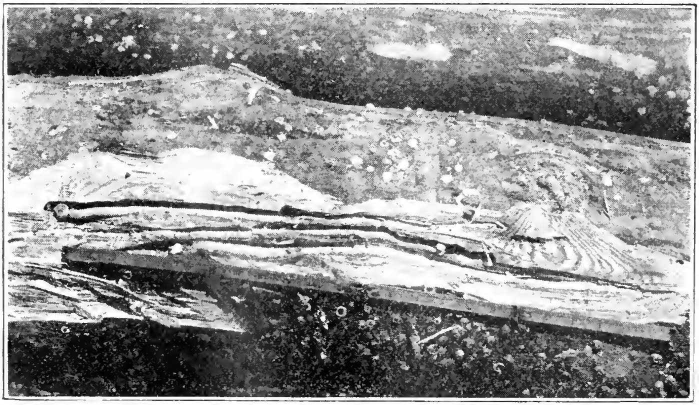


Fig. 4. The shipworm, or teredo

This animal does a vast amount of injury to piers and wharves by boring into timbers that are kept in salt water. The teredo is not a worm but a relative of the clam. The one in the picture was nearly 20 inches long and made a hole about 5/8 inch in diameter. Hundreds of thousands of holes cut into a log in all directions will soon ruin it. (Courtesy of National Research Council)

example, the teredo worm (which is not a worm at all, but a kind of clam) honeycombs the timbers of a harbor so that at last a large wharf crashes down (see Fig. 4); or a slowly growing forest gradually changes the stream flow or even the whole weather condition of a large and remote area.

Some of these changes produced by plants and animals are interesting to us because of their unusualness or their dramatic qualities. Others are of importance to us because they influence our own lives for better or for worse. Moreover, what is

going on inside of every animal and every plant may be of interest or importance to us in many ways. So, taking it all in all, the world of life offers many things for serious study as a life work or for interesting hobbies as pastimes, just as our own life is a constant challenge to our ingenuity and skill in solving problems and overcoming difficulties, whether we go at it like tackling a stiff job or like playing an absorbing game.

WHAT IS BIOLOGY?

1. Definition: *bios*, life; *logos*, study
   - What is science?
   - What is life—a kind of energy? a kind of stuff? what plants and animals do?
2. How biology is used
   - To protect useful plants and animals
   - To increase useful plants and animals
   - To improve useful plants and animals
   - To cure sickness
   - To prevent sickness
   - To lengthen life
   - To help us understand ourselves
   - To help in the management of plants and animals
   - To help in the management of human beings and affairs
   - To give pleasures of various kinds
3. What there is to study about things
   - Kinds, classifications, and names
   - The distribution of plants and animals on the globe
   - Conditions under which different living things live
   - The plants and animals of past times
   - How life is carried on
   - The structure of plants and of animals
   - How the parts of living things work
   - The origin of different kinds of plants and animals
   - Why ancient forms disappeared
   - The uses of various species
   - The injury that various species may cause
4. What makes biology interesting
   - That depends upon individual taste
     - Interest in classifying and in collecting
     - Interest in discovery of new facts

Interest in understanding relationships
Interest in increasing usefulness
5. How biology is studied
We pick up odds and ends of information
Observation of plants and animals and their activities
Comparison and classification of forms, structures, and activities
Tests and experiments; second-hand learning
6. What plants and animals do to us
Produce changes in our surroundings and in us
Useful changes; harmful changes; indifferent changes
Produce materials and objects that we can use

QUESTIONS

1. What ten animals do you know by name when you see them?

2. What ten plants do you know by name when you see them?

3. How does a living plant differ from one that has ceased to live?

4. How does a living animal differ from one that has ceased to live?

5. In what ways does a living plant resemble a dead one?

6. In what ways does a living animal resemble one that has died?

7. How does a living plant differ from an object that has never been alive? a living animal?

8. How does a living plant resemble a living animal?

9. Give three examples of making use of electricity, although we do not know exactly what electricity is.

10. What else can we use without having full knowledge of it?

11. Give three examples of having better use of anything after getting a better knowledge of it.

12. Give five *facts* that you know about some plant or plants without ever having studied them; about some animal or animals.

13. Name all the occupations that you know about which make use of knowledge concerning living things. Name some which do not.

14. Make a list of ten questions that have occurred to you in the past about plants and animals, whether you know the answers to them or not.

CHAPTER II

WHAT KINDS OF THINGS ARE LIVING?

Questions. **1.** Can all living things move? **2.** Can plants feel? **3.** Can insects hear? **4.** Are plants alive in the same way as animals are? **5.** Are animals alive in the same way as we are? **6.** Can plants protect themselves?

8. Great variety among living things. At first thought living things differ so much among themselves that to many people it seems hopeless to find out what they have in common. How shall we begin to compare the eel and the elephant, the cow and the cabbage, the spruce and the sparrow? We may begin by dividing our problem up into sections, and then examine some material to solve each section separately. First we can profitably consider general forms and structures, then chemical characteristics, and finally the behavior, or doings, of living things; for, after all, it is what plants and animals *do* that most concerns us. And we may proceed by studying a representative plant with two or more representative animals.

9. A whole plant. If we examine a geranium plant, or any other small plant that is easily handled, we find that the part which is usually below ground (the **root**) differs from the part above the ground (the **shoot**) in several ways. There is a difference in color and a difference in texture; the smallest branches or subdivisions of the root are, as a rule, more delicate than those of the shoot. The shoot also has parts which we easily distinguish (in most kinds of plants) as **stem** and **leaves**; and the leaves differ from the stem in shape, color, and texture.

At certain seasons of the year the stem bears other structures besides leaves, namely **flowers**. In most kinds of plants the flowers last but a short time and are succeeded by **fruits**, inside of which there are usually **seeds.**

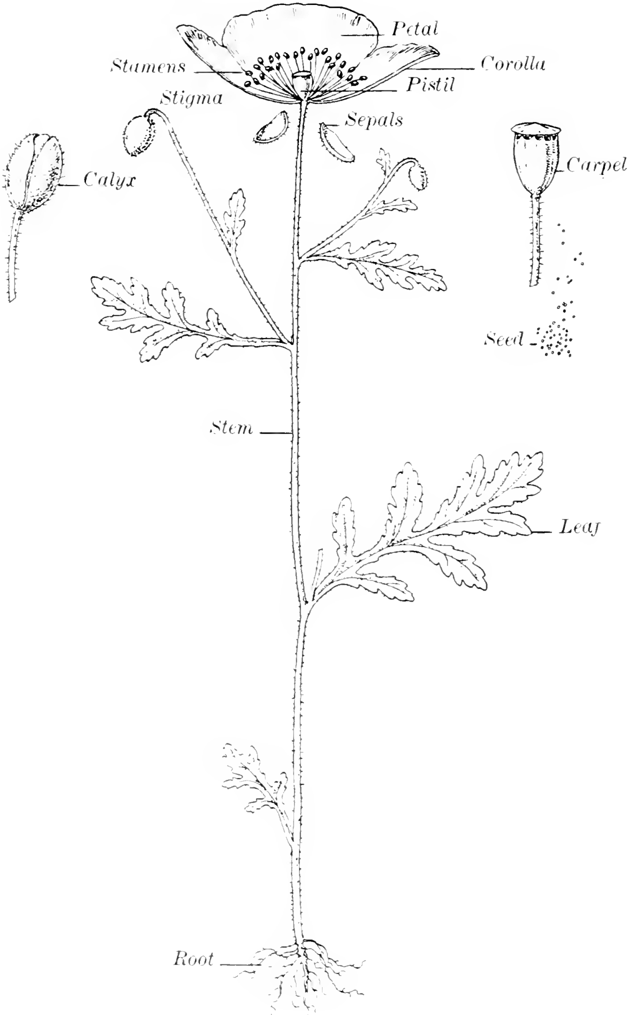


Fig. 5. A whole plant

Like most of the familiar plants, the poppy consists of an underground portion, the *root*, and of a portion aboveground, the *shoot*. The shoot is made up of *stem* and *leaves*, and on special stems or stalks there are special clusters of leaves which together make up the *flower*

10. A representative insect — the grasshopper (*Acridium, Melanoplus, Caloptenus*, or some other genus). If we examine a grasshopper, we find the general plan of structure to be that of a main body with several kinds of outgrowths. The body has three easily distinguished regions: the **head**, the **thorax**, and the **abdomen**.

The head bears two feelers, or **antennæ** (singular, *antenna*), projecting forward, and the **eyes** occupy a large part of the surface. These large eyes are called *compound*, because each consists of numerous complete eyes (see Fig. 6). In addition there are three tiny *simple* eyes on the front of the head. The **mouth** occupies the end of the head which is toward the ground when the animal stands in the normal position, and it consists of several distinct parts.

The thorax, which is covered by the **wings** when the animal is at rest, is made up of three more or less distinct **segments**, or rings. Each of these carries one pair of jointed **legs**. Two of the segments carry one pair of **wings** each, and the *anterior* (forward) wings cover the *posterior* ones when at rest.

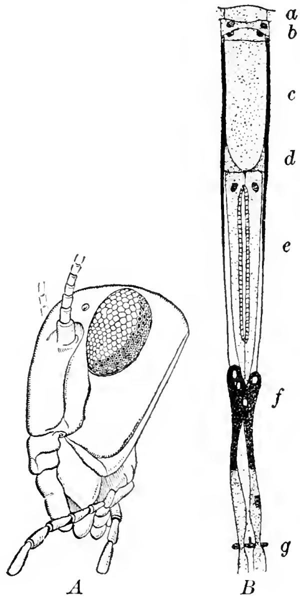


Fig. 6. Compound eye

In the *Arthropoda*, or jointed-legged animals, there are compound eyes as well as simple ones. *A*, head of a locust, showing the compound eye with its many facets, each representing the exposed surface of an *ommatidium*, or single eye. *B*, an ommatidium, seen in section cut lengthwise. *a*, corneal lens; *b*, lens-growing cells; *c*, cone; *d*, iris cells; *e*, retinal cells, receiving light impressions; *f*, retinal pigment; *g*, perforated supporting membrane

Coming to the abdomen, we find that this too is segmented. Indeed, in the whole class of animals called *In-sects* the body is cut up, or segmented, like the body of an earthworm. On the side of each segment there is a tiny **spiracle**, or breathing hole (see Fig. 7). The foremost seg-

ment has on each side a small eardrum, or **tympanum** (see Fig. 8). The hindmost segment bears special structures that have to do with the throwing out of refuse (*feces*), and others connected with reproduction. In the female these terminal parts together constitute the *ovipositor*, or egg-laying organ.

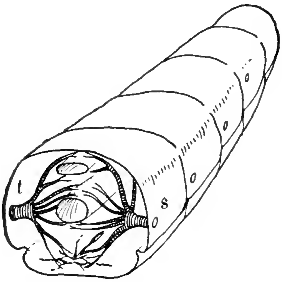


Fig. 7. Breathing tubes in insects

s, the spiracles in the side of the body, opening into the tracheæ *t*, which branch repeatedly and bring air to all the tissues

11. A representative mammal—man (*Homo sapiens*). We are so familiar with this species that we need merely to recall the main features of the outward form and structure. Like the insect, this mammal has a main body, with a distinct head at the anterior end and appendages (two pairs) attached to the trunk—one pair at the anterior end (the arms), the other pair at the posterior end (the legs). We see, further, that both animals have a definite bilateral (two-sided *symmetry*, the right and left halves being almost identical in form (*although opposite in placing and facing*). Certain *kinds*

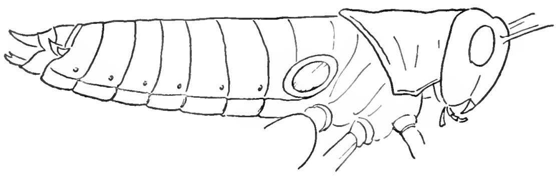


Fig. 8. The main divisions of an insect's body

In the grasshopper, as in other insects, the body is made up of a rather distinct *head* at the front end; the main "trunk," or *abdomen*; and, between these, the *thorax*, which bears both the legs and the wings. Near the front end of the abdomen the grasshopper has a rather large eardrum

of parts are common to the two animals, although these corresponding parts (for example, mouth, ear, eye, leg) are very different in structure; and there are other differences which

appear when the two forms are compared. Yet we consider both types to be *living things*, and we class both as *animals*.

12. Organs; organisms. Now, what similarities can we find among living things in general? If we consider merely the three examples so far discussed (a seed plant, an insect, a mammal), we find, first of all, that each has a number of distinct parts. If we examine each of these parts more closely, we find that each part is made up of several different kinds of *material*, arranged in a particular way. Moreover, if we looked into the *interiors* of the insect, the plant, and the mammal, we should find in each case some more distinct parts. Indeed, most of us already know that our own bodies have such parts as brain, stomach, liver, kidney, heart, and bladder.

This brings us to a third important fact. Each of these parts is something more than a *structural unit*, like the many bricks which make up a wall. *Each one carries on a particular kind of work or behaves in a particular way in relation to the others or in relation to the plant or animal as a whole.* Accordingly we get the idea that each of these parts is an *organ*, or instrument, which performs some special service, or *function*, in relation to the others or in relation to the whole body.

Any plant that you know is made up of organs; any animal that you know is made up of organs. We may therefore call a plant or an animal an **organism**. To be sure, not all plants or all animals have exactly the same organs; and, as we shall see, the organs of some plants and animals are not easily distinguished. Nevertheless, the term *organism* is a convenient one to use, meaning a living thing.

13. Chemical characters of organisms. People have long searched the bodies of plants and animals for something that will distinguish organisms *chemically* from non-living things. May there not be some substance or substances peculiar to organisms, something that makes the real difference between living and non-living?

The moment we start chemical tests with living things we are likely to kill them, or at least to change them in some important

way. Yet we now know enough to say rather positively that the *chemical elements* of which human beings and other organisms consist are exactly the same as those found in the air, in the waters, and in the soil and rocks that make up our world (see Fig. 3). At the same time, plants and animals contain *compounds*, or combinations of these elements, that *occur naturally only in living things.* Examples of such are starches and sugars, fats and oils, proteins and amino acids, and chlorophyl and other pigments. All such substances have accordingly been called *organic*, to distinguish them from water, salts and other minerals, metals, etc., which are called *inorganic.* Organic compounds are present in *all* plants and animals.

Within the last hundred years chemists have been able to reproduce a large number of substances that ordinarily originate only in the bodies of plants and animals; and they have made up new compounds along similar lines, that are never found in nature.

14. Activities of animals. As we watch our grasshopper and our plant we are at once reminded of a striking difference between them: that is, the liveliness, or **movement**, of the animal as contrasted with the quietness of the plant. Since we are looking for *similarities*, we are tempted to set this point aside and search for other features; but let us keep the facts before us without prejudice, and let us complete our record of the grasshopper's activities before making up our minds which are important for our purpose. Very well, then, the grasshopper *moves.* He not only moves from place to place, but he moves parts of his body in relation to one another, as the antennæ and the parts about the mouth. These movements at once suggest other activities; the mouth movements suggest **eating**, and the movements of the antennæ suggest **feeling**.

From our experience with food we already know that it is related to **growing**; and while the grasshopper does not increase in size under our eyes, we know that he must have grown, for he was not born full size. And that suggests another thing that animals do—they **reproduce**.

Returning for a moment to *feeling*, we can easily convince ourselves that there is more to the antennæ than a mere wild waving. There is about the animal something that makes it move under certain outward conditions which act upon these feelers. Moreover, there is something about the animal that makes it move under certain conditions which act upon the eyes.

Without looking into the interior of the animal we can learn that it takes food and grows, that it feels or sees and moves, and that it reproduces. And so much we can say of all the animals we know. Some eat one kind of food, some another; some grow rapidly, some slowly; but all take in food and grow. So, too, animals differ as to how sensitive they are, as to what kinds of conditions influence them, and as to how rapidly or how vigorously they move; but all are sensitive to changes and all do move. And all animals originate from other animals; that is, all species of animals reproduce themselves.

15. Activities of plants. What now of our plant? Does it also move? Is it sensitive to what goes on around it? We know very well that plants *grow*, and everybody who has ever thought of getting new plants for any purpose knows that they commonly come from seeds, and that these seeds in turn come from other plants. Plants, then, do reproduce themselves. But if plants really do move, and if they really do respond to changes in their surroundings, most of us have not noticed these facts. Still, the very fact of taking in food, which is essential to growth, implies some movement. To be sure, plants do not reach out and grasp food, as do the grasshopper and the baby, for example; nor does the plant eat with a mouth; yet it does take materials into itself from the surroundings (by way of the roots and by way of the leaves), and it transports, or moves, these materials from one part to another.

Most of the movements in a plant are slow and minute, so that we should need a microscope to observe them directly. But the rapid movement of the leaves in a disturbed sensitive plant, and the slower but very distinct turnings of many common plants under one-sided illumination, are easily observed.

These movements show us, at the same time, that plants are really very sensitive to what is going on around them, although, compared to animals, they respond rather slowly (see Fig. 9).

Thus we find that plants and animals have in common certain processes or functions—food-taking and growth, irritability (or sensitiveness) and movement, and reproduction. There are, to be sure, many differences also; plants and animals differ very

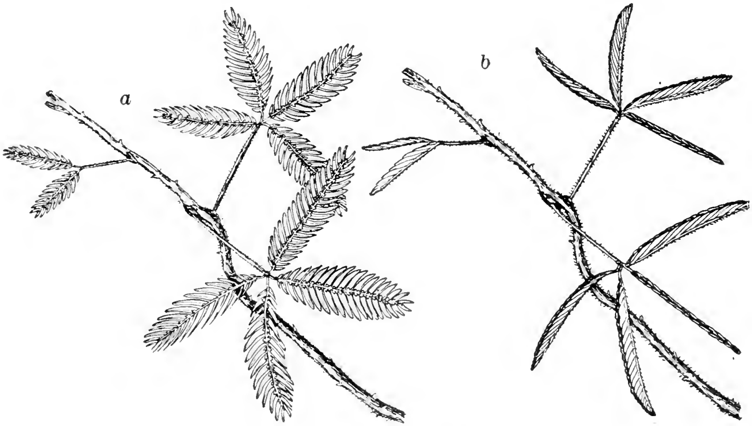


Fig. 9. Sensitive plant (*Mimosa pudica*)

a, leaves in normal position; *b*, leaves folded after disturbance. It is not necessary for us to assume that this movement is of any real value to the plant. It is true that in the new position the leaf exposes less surface and sheds the water better. But hundreds of plants with similar leaves have no difficulty in shedding rain without being so sensitive. Many plants (clover, oxalis, and others) droop their leaves in the dark in a few minutes. It is possible that in the clover and others the drooping of the leaf is the direct result of reduced transpiration. But that does not give the plant any advantage. It is very likely that the sensitive plant is simply more sensitive than any of its relatives (the bean family), many of which are sensitive in the same way but not in the same degree

much as to the materials which they take in from the outside, for example, and as to the way in which they make use of this material; but we are now considering their common characteristics.

16. Comparison with non-living things—growth. The fact of **growth** is universal for living things. Yet the crystals of

many substances also grow, some of them very rapidly, so that we can actually see them grow. Most of us have seen icicles grow. If by growing we mean simply becoming larger, then crystals and icicles grow just as truly as beets or babies. What, then, is the real difference between the two kinds of growth?

When an icicle becomes larger, it does so by adding new layers of ice-stuff (water) on the outside. The growth of a crystal proceeds in the same way. A baby, however, does not grow in this manner.

1. The baby grows not by the addition of baby stuff from the outside but by the *addition of different kinds of material*—such as cow material (milk), or hen material (eggs), or wheat stuff (bread).

2. The growth material is not added on the surface, but *is taken in*.

3. The new additions do not remain the same kind of material, but *undergo chemical changes* and become at last baby stuff.

4. The growth of the baby goes on not merely by the extension of the surface; *it takes place in all parts* at once, inside parts as well as outside parts growing.

These differences between the two kinds of growth may be summarized by saying that the icicle grows by **accretion**, whereas the baby and other living things grow by **assimilation**. By accretion we mean the addition of material on the surface. By assimilation we mean the transformation of foreign material into the material of the body, the "making alike" of stuff that is different.

17. Movement. Most of the animals that we know are capable of moving about and of moving their parts. Many non-living objects also move, as the clouds and the waves. But these bodies do not move because of anything that takes place inside. We recognize that they are being pushed about by outside forces. In living plants and animals there are movements going on *inside the organism*. Some of these inside movements result in the movements which are outwardly visible.

18. Irritability. We ourselves perceive lights and colors, sounds, odors, and tastes. The movements of the familiar animals show that they are disturbed by much of what happens about them, and these disturbances are different from the kind that is caused when a cup is dropped, for example. A dog does something when he is hurt. Your eye does something when a sudden flash of light is presented. Even a geranium plant changes its behavior when placed in a sunny window. This sensitiveness of living things is in some ways the most remarkable fact about them.

Yet we shall find that sensitiveness is not altogether confined to living things. There are certain chemical compounds that are in some ways even more sensitive than plants and animals. Some compounds are so sensitive to mechanical disturbance that they will produce a violent reaction when they are dropped, as in the case of dynamite, which is by no means the most sensitive. This material is sensitive also to heat. If a hot poker is applied to a stick of dynamite, the results are said to be more disastrous than the consequences of poking a vicious dog.

19. Fitness. There is one respect, however, in which the sensitiveness of living things differs from the sensitiveness of non-living things. In most cases the living body responds to a disturbance by doing something that will *probably save it from further injury*. The non-living body, when sufficiently disturbed to do anything, does something that generally results in its further injury or destruction. Thus, when a dog's tail is pulled, he will try to run away, or he will bark or snap at the "thing-holding-tail." These responses are, on the whole, of a kind that will save him from further damage. Indeed, we cannot imagine how living beings would continue to live, generation after generation, if they had the habit of doing things that tended to injure or destroy them. In contrast to this kind of behavior, think of what the stick of dynamite would do if touched with a red-hot poker. There is nothing here that looks in the least like "trying-to-save-itself."

20. Origin. We do not know anything about the first appearance of life upon the earth, but we do know that every plant and animal now living had its origin in the body of some other plant or animal. In general, non-living bodies do not reproduce themselves; they do not produce other objects, either like themselves or different; but, so far as we know, living bodies can be produced only by other, similar, living things.

WHAT KINDS OF THINGS ARE LIVING?

1. Great diversity among living things
    - Need for breaking up material for comparison
    - Forms — Chemical composition
    - Structures — Activities
2. The parts of a plant (seed-bearing)
    - Root
    - Shoot
        - Stem
        - Leaves
        - Flowers
        - Fruits (seeds)
3. The parts of an insect (grasshopper)
    - Head
        - Mouth
        - Eyes
            - Compound; simple
        - Antennæ
    - Thorax (segmented)
        - Legs
        - Wings
    - Abdomen (segmented)
        - Breathing organs (spiracles)
        - Hearing organs
        - Reproductive organs
4. The parts of the human body
    - Head
        - Mouth
        - Eyes
        - Nose
        - Ears
    - Trunk
        - Arms
        - Legs

5. Comparison of insect with mammal

Similarities	Differences
Bilateral symmetry	Segmentation in insect, not in mammal
Distinct head	Distinct thorax and abdomen in insect
Special organs that correspond in function	Wings
Mouth	Number and location of legs
Eyes	Differences in corresponding organs
Ears	Grasping hand in man
Breathing openings	
Legs	
Paired appendages	

6. Organs; organisms; organic
    - Peculiarities of plant and animal parts
        - Structural features
        - Functional features
            - Related in action to one another
            - Related in action to body as whole
    - All plants and animals made up of organs
    - Living things as organisms
    - Chemical peculiarities of organisms
    - Organic and inorganic compounds

7. Activities of animals / Activities of plants

Activities of animals	Activities of plants
Growth	Growth
Food-taking	Food-taking
Irritability	Irritability
Movement	Movement
Reproduction	Reproduction

8. Comparison of living things with non-living things

Growth	Movement
By assimilation	Irritability
By accretion	Fitness
	Origin

QUESTIONS

1. In what different ways is the grasshopper able to move about?

2. What special organs does the grasshopper use in each kind of locomotion?

3. What is there about each of these organs that fits in with the special kind of locomotion that it serves?

4. Under what circumstances is each form of locomotion used?

5. In what way does the ability to move about help the grasshopper?

6. How might an organism be able to keep alive without any means of locomotion?

7. Of what movements is the grasshopper capable, other than those of locomotion?

8. How do these movements help in the life of the grasshopper?

9. What is there about the organs of locomotion that fits them for the special work they do?

10. How could an animal get along without the ability to carry on these movements?

11. What kinds of organs can you find in the grasshopper but not in the human body?

12. In what way are any of these organs essential to life?

13. How are the corresponding functions carried on in your own body?

14. How are the corresponding functions carried on by a plant?

15. Make a table of four vertical columns headed:

Functions	Grasshopper	Man	Plant

In the first column (functions) list all the distinctive activities and processes of living things.

In the second column name the structures or organs of the grasshopper that are related to the corresponding functions or processes.

In the third and fourth columns carry out the same idea for man and for a plant respectively.

REFERENCE READINGS

Densmore, H. D. General Botany, pp. 14–19.

Gager, C. S. Fundamentals of Botany, chap. ii, The Parts of a Flowering Plant.

Lutz, F. E. Fieldbook of Insects.

Folsom, J. W. Entomology, with Special Reference to its Biological and Economic Aspects, chap. ii, Anatomy and Physiology; sect. 1, Skeleton (pp. 21–56), sect. 2, Integument (pp. 56–68).

Farmers' Bulletin 606, Collection and Preservation of Insects and Other Material for Use in the Study of Agriculture.

Hough and Sedgwick. The Human Mechanism, chap. i, The Human Mechanism.

CHAPTER III

SOME LIFE RELATIONSHIPS: BUTTERFLIES AND BEES

Questions. 1. In what ways are different kinds of insects alike? 2. Do all bees sting? 3. How do bees sting? 4. Can butterflies bite or sting? 5. Can moths bite? 6. How do moths destroy cloth or fur? 7. Upon what do butterflies feed? 8. In what ways are butterflies and moths useful to mankind? 9. How are butterflies and moths injurious to man?

21. The butterfly. The butterfly belongs to the same *class* of animals as does the grasshopper. The general plan of the body is the same—head, thorax, abdomen. The number of legs and of wings is the same, and the arrangement of these organs is the same. The butterfly has antennæ and compound eyes, as has the grasshopper. But with all these resemblances nobody is likely to mistake one of these animals for the other.

Let us examine carefully a butterfly (or moth). We find that *every organ is in some way distinct* from the corresponding organ of the grasshopper. On the other hand, *every organ of the butterfly follows the general plan of the corresponding organ of the grasshopper.* Even the mouth, which shows perhaps the greatest differences, can be seen to follow the same general plan.

A comparison of the *behavior* of butterflies with the behavior of grasshoppers brings out still more striking differences, as well as important similarities. Suppose we answer for both animals such questions as How does it find its food? How does it take in food? How does it get impressions from the outside? How does it move about? How does it breathe? How does it reproduce? Two facts are very likely to impress us:

1. Corresponding organs carry on corresponding functions.

2. Differences between corresponding organs are related to differences in the surroundings and habits.

Thus, locomotion is brought about by means of legs and wings. Both insects breathe through spiracles arranged in a row on each side of the abdomen. Food is in both cases taken in by the mouth; but the grasshopper has a biting or chewing mouth, whereas the butterfly has a sucking mouth.[1]

22. Development of the grasshopper. If we study the whole life of these insects from the beginning to the end, we shall find some more interesting similarities as well as differences. The mother grasshopper lays her eggs in the ground, where they remain the whole winter. When the young hatch out they look like tiny grasshoppers without wings, and their heads are

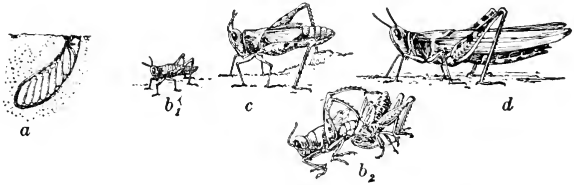


Fig. 10. Red-legged locust (*Melanoplus femur-rubrum*)

a, eggs in the ground; b_1, young wingless larva; b_2, larva molting; *c*, pre-adult; *d*, adult insect

rather large in proportion (see Fig. 10). The animal begins eating almost immediately, but for a time it does not increase in

[1] When making comparisons between various organisms we must be constantly on our guard not to read into our observations more than the facts allow. For example, it is a very easy matter to state what we observe about the mouths of the insects in this way: "The mouth of this insect has biting jaws, since it feeds upon solid food, whereas the mouth of the other is a sucking mouth, since it feeds upon fluids." A little thought will show us that it would be just as true to say: "The grasshopper feeds upon solids, since it has a biting mouth, and the butterfly sucks nectar from flowers, since it has a long, sucking mouth." In other words, all we really know, from our observations, is that the structure of each animal somehow fits in with its activities or habits—that each animal uses its organs in its own particular way. *We do not know how each kind of animal came to have the structures and habits which we find it to have, or how it came to have the ways of living that it has.* There are many attempts to explain what we find, and we shall study some of these proposed explanations later.

size, for its outer covering, the **exoskeleton**, is of rather hard material that can neither grow nor stretch. After some days, however, this exoskeleton splits lengthwise on the *dorsal* side (the back, or side away from the ground), and the animal crawls out, head first (see Fig. 11). Now, with no stiff exoskeleton to interfere, the insect grows rapidly for a short time, until a new exoskeleton is formed by the hardening of a substance which is secreted, or given off, by the skin. The process of casting off the exoskeleton is called **molting**. From time to time the insect molts again, gaining in size after each molt; and with each molt there are other visible changes, such as the development of the wings and the altered proportions of the parts. After the fifth molt the animal is full grown.

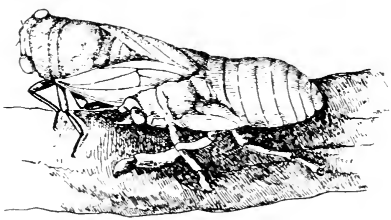


Fig. 11. Molting cicada

In many jointed-legged animals (*Arthropoda*) the growth takes place at intervals between molts. The hard outer skeleton breaks open and the soft-skinned animal crawls out. After a while the shell hardens and the growth of the animal stops again

23. Development of the butterfly. The mother butterfly usually lays her eggs upon the leaves of some plant. When the young hatch out they resemble the parent so little that many people never discover the relation between the wormlike caterpillars and the beautiful adult moths and butterflies which are their parents, and into which caterpillars in time develop.

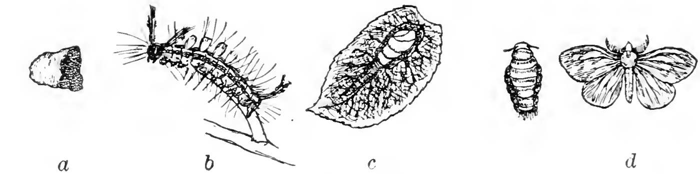
The **larva**, or young butterfly in this caterpillar stage, begins at once to feed upon the leaves. The animal now has a biting mouth: the jaws work right and left, very much like those of grasshoppers. A young larva eats several times its own weight of leaves in the course of a day, and it grows very rapidly. Although the caterpillar looks more like a worm than like any familiar insect, a closer examination shows many resemblances to insects. The head is fairly distinct, and the rest of the body is segmented. The first three segments behind the head, corre-

sponding to the thorax, bear small legs; but no wings are to be seen. Unlike adult insects, the caterpillar of some species bears several pairs of legs on some of the abdominal segments.

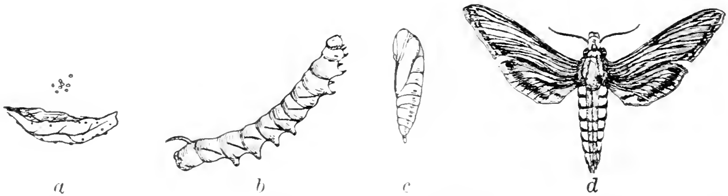
After reaching full growth as a caterpillar the animal goes into a resting stage, in which the exoskeleton becomes very hard (see *c*, Fig. 12). Among the moths the resting stage generally includes a silky covering, or **cocoon**, about the exoskeleton, as in the case of the silk-moth. This resting stage may last from a few weeks to several months, according to the species. Among many species in temperate regions it lasts over the winter. The **pupa**, whether in a cocoon or naked, *appears* to be perfectly lifeless, but we know that great changes are taking place inside. When these changes are completed, the pupa breaks open, and out crawls the fully formed butterfly adult, or **imago**.

24. Metamorphosis. The great differences in appearance and structure between the adult butterfly and each of the other stages through which it passes in the course of its life history (egg, larva, pupa, imago) have long aroused the wonder of observers. The succession of changes from one stage to the next is called **metamorphosis**, which means the same as *transformation*, that is, a changing over from one form to another. Metamorphosis in development is found among many kinds of insects, but not among all. The development of the grasshopper is said to show an *incomplete* metamorphosis, since at each stage the change is not so great as that observed among butterflies. Metamorphosis in development is found also among higher animals, such as the newt and the frog, although in these cases the stages do not correspond exactly to the four stages in the butterfly's life (see section 227).

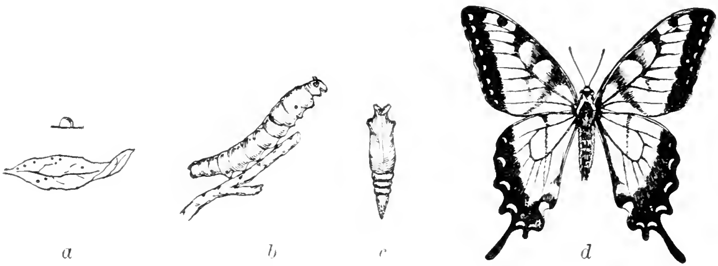
25. The bee (*Apis mellifera*, honeybee; or *Bombus* sp., bumblebee). Insects of the *order* represented by the honeybee and the bumblebee differ in many ways from both the grasshopper and the butterfly. We see again the same general plan of body, consisting of head, thorax, and abdomen; the same number and arrangement of legs and wings; the same type of food-getting and sensory organs. Moreover, there is a segmentation of the thorax and of the abdomen, and there are spiracles



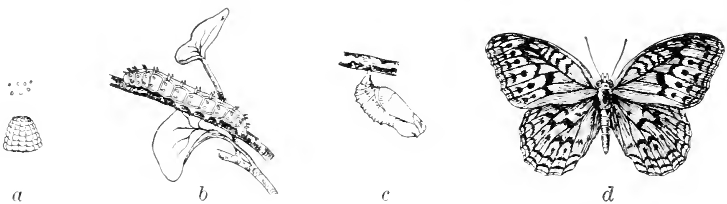
Tussock moth (*Notolophus*)



Hawk moth (*Hyloicus kalmiae*)



Yellow swallowtail, or tiger butterfly (*Papilio turnus*)



Fritillary (*Argynnis*)

Fig. 12. Development of *Lepidoptera* (moths and butterflies)

The egg, *a*, hatches into a wormlike larva, or caterpillar, *b*. The larva feeds voraciously and grows very rapidly. On reaching full growth it curls up, secretes a hard covering, and goes to sleep. In this resting stage, or *pupa*, *c*, it may remain for months, giving no outward sign of life whatever. At the end of the resting period the cover of the pupa breaks open, and out crawls the fully formed insect, *d*. In some species the two sexes have distinct forms or color patterns in the adult stage. In the tussock moth the adult female is a sluggish, wingless animal. (All about $\frac{3}{4}$ size)

by means of which the animal breathes. But there are distinctions in wings and legs and mouth, as well as in other details in all parts of the body. In development the insects of this order (which includes wasps and hornets, ichneumon flies and ants) show a complete metamorphosis.

26. Division of labor. One of the most interesting facts about the bee and ant order (*Hymenoptera*, see page 84) is the comparatively high development of *social* habits. The beehive and the ant colony have for ages represented to students a wonderful example of the possibilities of social life. There is complete

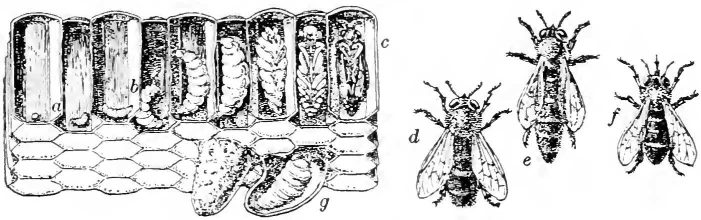


Fig. 13. The honeybee

The insect develops from an egg, *a*, into a tiny wormlike grub, or *larva*, *b*. The larva feeds upon material in its chamber, or cell; the food is supplied by adult bees. When the larva reaches its full growth (in about five days), the cell is closed with wax; during the resting stage, or *pupa* period, *c* (which lasts about thirteen days), the insect is transformed into an adult. There are three kinds of individuals: *drones*, or males, *d*; *queens*, or females, *e*; and workers, *f*. The queen develops in an extra large cell, *g*, which projects above the surface of the comb and is supplied with special food. (The larvæ are shown rather stretched out in their cells; they really lie at the bottom curled up in a ring)

coöperation of large numbers of individuals, year after year, without any sign of friction or conflict within the group. There is also a marked degree of what we call *division of labor*, whereby each individual attends to a single part, or a very few parts, of the total work done by the colony as a whole. Among the bees cells are constantly being built of wax. Honey is being made; nectar gathered. Prepared food is being stored in the cells. After the eggs hatch out, the young larvæ are looked after. At any given time the gathering of material, the storing of food, the nursing of the young, the cleaning of the hive, the building

of cells, are all carried on by different individuals; yet there seems to be no central government or directing officers. Each bee goes about her affairs just as regularly, and we might say as reliably, as does any solitary butterfly or grasshopper; yet all work together in perfect harmony to produce results that could not be brought about by individuals working separately.

In the bee colony there are three different kinds of individuals produced—males, females, and workers. In any one nest or hive there is but one female, the queen, and (during the summer) a number of males, or drones. The hundreds or thousands of other bees are workers, which are really females that do not

Fig. 14. The sting of the bee

In this order of animals the weapon is the egg-laying organ. When the bee stings someone, the point is likely to remain in the flesh; and as the animal flies away some of its internal organs are mutilated and the insect soon dies. The value of this weapon is not so much for the protection of the individual as for that of the colony or species. The individual is sacrificed to protect the group or to educate the enemies of the species

develop all their organs completely. Much of the time there are no drones, for the male dies immediately after the female is fertilized in the spring, and any other males are killed by the workers on the approach of winter. There is here, then, first of all, a division of labor between the reproducing individuals and the individuals that do all the other kinds of work that have been mentioned. But is there a particular class of workers for each particular class of activity? Among the honeybees the young adult, or imago, immediately after coming out of the pupa stage, sets to work as nurse, looking after the larvæ, which have to be fed for a few days after hatching from the eggs. Later these same adults turn to other work within the hive, and after a few days more they go forth to gather pollen

and nectar from flowers. Thus the division of labor is not between one kind of individual and another, but between one period of life and another — like the division of labor in some factory in which the younger workers make the parts for the manufactured product and the older workers assemble the parts.

27. Interdependence. The division of the total work of the beehive or the ant nest has been compared (1) to the similar division of labor among human beings in society and (2) to the division of functions among the organs of any plant or animal. The individual bee, for example, continues to live by carrying on many fairly distinct processes—eating, breathing, feeling, moving, and so on. We have already seen that there are special organs that carry on these special processes. The mouth is a food-taking organ; the leg an organ of locomotion; the eye a seeing organ; and so on. Now, in the case of a single organism, as in the case of a colony or society, division of labor means the *dependence* of one part upon all the others. *The mouth can take in food only if the wings bring the insect to the flower.* But that in turn depends upon *the eye seeing the flower.* Moreover, the wings and the eye and the mouth cannot do their work unless the food taken in by way of the mouth is somehow changed into a usable form and then distributed to the muscles of the wings, the nerves of the eye, and the complex machinery of the mouth. And, finally, the parts have to work in harmony or balance, and their activities have to be timed so that they fit together effectively. There is thus a certain *interdependence* among the parts, as well as a *correlation.*

This idea of interdependence applies not only to the relation among the parts of the organism or among the members of a colony or society; we see it illustrated also in the dependence of different species upon each other. The bee, for example, depends upon the clover for pollen and nectar to make food and wax. The clover species, in turn, depends upon the bee to render the important service of *transportation.* The formation of seeds in flowers remains in many species impossible unless some insect first carries the pollen from the organ in which

it originates (the *stamen*) to the seed-bearing organ (the *pistil*) (see page 42). The bees and the butterflies represent two groups that are most generally active in this process of *pollenation* (see Chapter IV). This interdependence between insects and seed-bearing plants is in some cases so great that certain orchids are dying out because the insects necessary for pollenation are not sufficiently abundant to insure seeds every year. In other cases insects introduced in a new region cannot maintain themselves because the needed food plants are not present. In our regular horticulture it happens occasionally that trees or bushes in full blossom fail to yield the expected crop of fruit because of the lack of insects to insure pollenation. This is why wise farmers and orchardmen so often maintain hives of bees: even where the honey itself is not considered worth producing, the bees are worth having because they insure abundant pollenation at the right time.

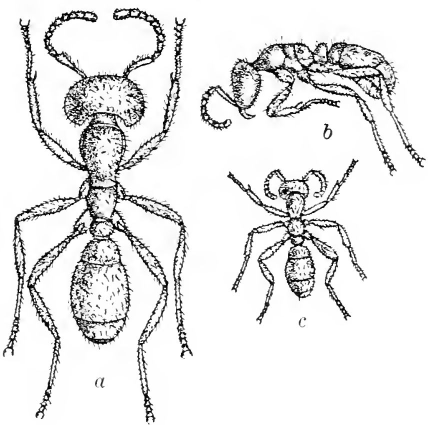


Fig. 15. Division of labor among ants

Three forms of the Central American fighting ant (*Cheliomyrmex nortoni*): *a*, soldier; *b*, medium worker; *c*, small worker

28. Homology. The division of labor among the organs of the bee is of course the same as that which we find in other insects, or even in entirely different classes of animals such as our own bodies; but if we compare the insects already studied with one another, we shall find that most of the functions are carried on by corresponding organs in the different animals. Thus, the locomotive organs in bees, butterflies, and grasshoppers are the legs and wings, and in every case the position of the organ and the general plan of structure are the same. If we examine the

mouths, we shall again find many basic similarities in spite of the great differences. Among animals that are built on substantially the same plan the corresponding parts are said to be **homologous**. Thus, the thorax of one insect is homologous with the thorax of another insect. Moreover, the thorax of a butterfly is said to be homologous with the three distinct segments immediately behind the head of the caterpillar. We may also say that the three pairs of legs on one insect are homologous with each other, since they originate and develop in the same way, in spite of differences, as between the hind leg of the grasshopper, for example, and the front legs. In the same way we consider the "balancers" of a fly homologous with the hind wings of the butterfly and the wing covers of the beetle homologous with the front wings.

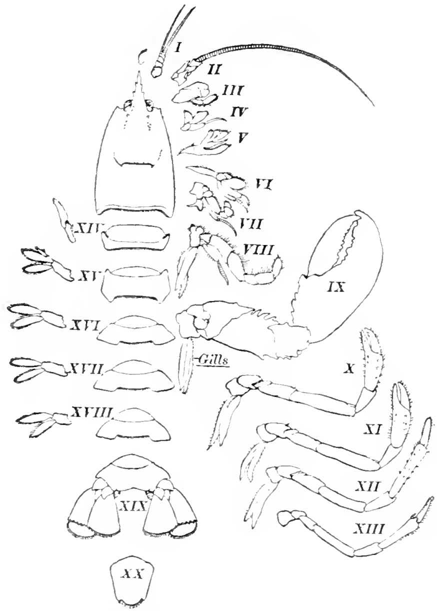


Fig. 16. Homology in the appendages of the lobster

In the *Crustacea* all the appendages are built on the same plan, but each segment of the body (represented by Roman numerals) has a distinctive organ. *I* and *II* are sensory; *III–V* combine sensory functions with food-getting; *VI–VIII* are chiefly food-getters, but are also related to breathing; *IX* is the nipper; *X* and *XI* are both grasping and locomotor organs; *XII* and *XIII* are walking legs. The abdominal appendages *XIV–XVIII* are called swimmerets and probably assist in slow swimming. *XIV* and *XV* are also related to reproduction in the male, and in the female all the swimmerets carry the hatching eggs and larvæ. *XIX* and *XX* spread out into a flat tail-paddle, used in swimming backward suddenly

The idea of homology helps us to understand a certain sameness among organs that appear to be very different in structure

or even in their functions. We can understand the bones of the arm, for example, much better if we compare them part for part with the bones of the leg; or the wing of a bird, if we compare it part for part with our arm (see Figs. 16 and 130).

29. Analogy. We have seen that there are several functions which are carried on by all living things, plants as well as animals—food-taking, breathing, responding to outward changes, reproducing. We have also seen that all the common plants and animals are *organized*; that is, made up of *organs*, or members, that share in the total work and that somehow correlate their functions. We have probably known these facts from early childhood, and it is very likely that human beings noted these facts early in the history of the race, for in every language common forms of expression take such facts for granted. For example, we speak of the legs of a lobster and the legs of a horse, the wings of a bird and the wings of a butterfly, the tail of a cow and the tail of a dragon fly. The two examples given for each name are not at all homologous; they do not correspond to each other as does the front wing of a butterfly to the hard wing of a beetle. In each pair named the two structures, or organs, resemble each other either in performing similar functions or in having a superficial similarity in position. The legs are walking organs; the wings are flying organs; the tails are relatively thinner parts of the animals, projecting at the posterior end.

Two organs of different type, or belonging to different types of organisms but *carrying on similar functions*, are said to be **analogous**. Thus, the jaws of a grasshopper may be considered as analogous to the jaws of a cow. They are not homologous; they are not developed in the same way, they are not constructed in the same way, and they are not operated in the same way; but in both cases the jaws are biting or chewing organs. The antennæ of a lobster may perhaps be considered analogous to the whiskers of a cat, but the claws of a lobster are neither homologous nor analogous to the claws of a cat.

When we compare plants with animals, we often find the same function carried on by organs that are so different that it is

not easy to decide at once which organs in one case are analogous to organs in the other; and as for homology, most people never discover any at all between plants and animals. Many plants have no special breathing organs that are strictly analogous to our nostrils or to the spiracles of insects, for they may absorb oxygen from the air at any part of their surface. Most plants have no organs that are analogous to the mouth which is present in most animals, for plants do not take food as we do, but simpler materials which they later work over into food. Plants have no organs that are analogous to the heart, for the circulation of material within the organism is in their case brought about by a totally different process. Even their irritability and their movements depend upon different structures.

On the other hand, the growth of plants, like the growth of animals, is a process that is carried on by every part of the body, and not by a special organ. Indeed, we shall see presently that all the fundamental functions are really carried on by all parts of the body. The idea of *division of labor*, the idea of *homology*, and the idea of *analogy* all correspond to real facts; but they do not apply to every detail of life.

30. Being alive. Whatever organism we may be thinking about, we shall always find that so long as it is alive it keeps on doing certain things, and that it remains alive only so long as it does these things, that is, so long as it (1) takes food and *assimilates* it, (2) transforms the assimilated material so as to get from it the energy for *movement* or for other processes, and (3) *responds* more or less suitably to changes going on around it.

Our own bodies and those of the other animals that we have studied are alive because they show **irritability**, **assimilation**, and **contractility**; and any other animal and any plant is alive because it is sensitive to changes, because it transforms material from outside into its own body, and because it can bring about movements or other changes that fit the conditions.

Like the insects that we have studied, every plant and every animal also originates from an egg or some other structure that is analogous or homologous to an egg.

SOME INTERRELATIONS OF LIVING THINGS: BUTTERFLIES AND BEES

1. The butterfly (class *Insecta*)
    - Resemblance to other insects
        - General plan of body
        - Appendages
            - Kinds
            - Numbers
            - Location
        - Sense organs
        - Feeding organs
        - Breathing organs
    - Distinctive characters of order *Lepidoptera* (moths and butterflies)
        - Structural
            - Head, thorax, abdomen
            - Legs
            - Wings
            - Mouth organs
            - Sense organs
        - Habits and behavior of special organs
2. Development of grasshopper
    - Egg stage (where eggs are deposited)
    - First active stage (nymph)
    - Molting
    - Growth between moltings
    - Other changes
    - Adult
3. Development of butterfly
    - Eggs
    - Larva
    - Pupa
    - Imago
    - Resemblances between larva and adult
    - Differences between larva and adult
4. Metamorphosis
    - In insects
        - Kinds
        - Stages
    - In other animals
5. The bee
    - Resemblances to other insects
    - Distinctive characters
6. Division of labor among social insects (for example, the honeybee)
    - Kinds of work done
    - Kinds of individuals
        - Work done by each
    - Advantages
        - To the colony
        - To the individual
    - Disadvantages
        - To the group
        - To the individual

7. Interdependence
    Division of labor among organs of an animal
        Kinds of work; kinds of organs; how the parts are coördinated
    Interdependence among social insects
    Interdependence within a human society
        Examples; advantages; disadvantages; limits
    Interdependence between species
        Example: insects and seed plants
            What it means to the insects
            What it means to the plant species
            Importance to man
8. Homology
    Corresponding parts or organs in any organism
    Corresponding parts or organs in different species of same type
    Examples of homologous organs that are very different in appearance or in function
9. Analogy
    Organs or structures of different types but having similar functions
10. Life functions of plants and animals
    Food-getting and assimilation
    Release of energy from food (movement and other changes)
    Irritability and adaptive response to outward changes
    Origin from previously existing organism (reproduction)

QUESTIONS

1. What similarities are there in the structure of grasshoppers and that of bees and butterflies?

2. What is alike in the activities and functions of grasshoppers, butterflies, and bees?

3. How do the structures of the grasshopper and the bee differ? of the grasshopper and the butterfly?

4. How does the structure of the butterfly differ from that of the bee?

5. In what respects does the behavior of the grasshopper differ from that of the butterfly?

6. How do the functions and activities of the grasshopper differ from those of the bee?

7. Contrast the habits of the bee with those of the butterfly.

8. What is there about the structure of these insects that protects them from possible enemies?

9. What do these animals do to protect themselves against enemies?

10. What are the important distinctions between the development of an animal and its growth?

11. How can we show that a human being develops as well as grows?

12. What division of labor is there among the members of a family?

13. What kinds of division of labor are there among the workers in an office? a store? a factory?

14. What determines the division of labor among the different states or natural regions of a country?

15. How does division of labor affect the independence of any given individual?

16. What are the advantages of division of labor within a profession?

17. In what other ways can these advantages be obtained?

18. What are the disadvantages of extreme division of labor?

19. How can these disadvantages be overcome?

20. In what ways do human beings depend upon other species of animals or upon plants?

21. In what ways do other living things depend upon us?

REFERENCE READINGS

Farmers' Bulletin 708, The Leopard Moth, a Shade-Tree Insect.

Farmers' Bulletin 701, The Bagworm, a Shade-Tree Insect.

Farmers' Bulletin 447, Bees.

United States Department of Agriculture. *Bulletin 1222*, Growth and Feeding of Honeybee Larvæ.

MAETERLINCK, MAURICE. The Life of the Bee (extract in C. H. Ward's "Exploring Nature," pp. 88–95).

LATTER, O. H. Bees and Wasps.

FOLSOM, J. W. Entomology, chap. iii, Development; sect. 2, External Metamorphosis (pp. 126–148).

CHAPTER IV

THE CYCLE OF LIFE: FLOWERS

Questions. **1.** Do all kinds of plants produce seeds? **2.** Do all kinds of plants bear flowers? **3.** What is the use of flowers to plants? **4.** How does the odor of a flower help the plant? **5.** How does the odor of a cultivated rose help the plant? **6.** How are seeds made? **7.** Can a plant of one kind produce seeds of a different kind? **8.** Are all bright flowers visited by insects? **9.** Do insects get anything from flowers besides nectar? **10.** Does it hurt plants in any way to remove the flowers?

31. Individual life is limited. The life of every individual, plant as well as animal, comes to an end after only a few minutes, or after many centuries; dying is a part of being alive. Yet the species, or kind, may continue to live for thousands and thousands of years. *New individuals are constantly being produced.* The species *reproduces* itself, although not every living individual can reproduce itself. The term **reproduction** carries the idea of a *special* portion being separated from the parent and developing into an individual. Among the more familiar plants, reproduction is by means of seeds. The **flower** is a special structure related to the making of seeds.

32. Structure of the flower. In most common flowers, such as wild roses or buttercups, we find certain leaflike parts that attract our notice because of their color. This conspicuous part of the flower is called the **corolla**, and is commonly surrounded by another set of leaflike parts that make up the **calyx**, or cup (see Fig. 17). Although this floral envelope (calyx and corolla) is in most plants the first to attract our attention, it is by no means the most important part of the flower. Many species produce seeds without having these organs.

33. The essential organs. The seeds originate from tiny structures called **ovules**, which are borne in special organs found at

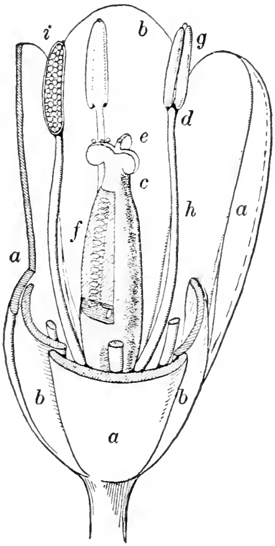


Fig. 17. Structure of a flower

The outer set of covering leaves, *a*, *a*, is called the *calyx*; the single parts are *sepals*. The inner layer, *b*, *b*, is the *corolla*; its parts are the *petals*. The central organ is the *pistil*; the main body of the pistil, *f*, is the *ovary* and contains one or many little structures (*ovules*) capable of becoming *seeds*. The tip, *e*, of the pistil is the *stigma*; this is connected with the ovary by the *style c*. Surrounding the pistil are a number of *stamens*, *d*, consisting of a stalk, *h*, called the *filament*, and an enlarged capsule, *g*, called the *anther*. This contains a mass of cells which can be thrown out, *i*; these cells loosened from the anther are called *pollen*

the center of the flower, called **carpels** (see Fig. 18). Sometimes there is a single carpel, as in the pea flower (*4*, Fig. 197); sometimes there are several. When there are two or more, they may be quite distinct or they may be more or less completely fused together (Fig. 18). The carpel may contain a single ovule (cherry, oak, strawberry), or a few (bean, apple), or very many (poppy, cucumber). The name **pistil** (from a fancied resemblance to the pestle, with which the apothecary crushes substances in his mortar) is sometimes given to the single carpel or to the combined carpels in a flower. The enlarged portion, bearing the ovule or ovules, is called the **ovary** (Fig. 17, *f*). The upper tip of the pistil is called the **stigma**, which means spot (Fig. 17, *e*).

Surrounding the pistil are several slender stalks with knobs or enlargements on the ends (see *d*, Fig. 17). These structures are called **stamens**, from a word meaning "thready."

Flowers differ greatly in size and shape, as well as in color and odor. The various parts differ in many ways as we compare the flowers of different species; but the pistils and stamens are always and everywhere the organs that have to do with seed-making, and their work is the same in all flowers. Because seeds are produced only by these organs, pistils and stamens are sometimes spoken of as the *essential* organs of the flower.

34. The ovary. If you cut open the ovary in any flower, you will find that it consists of a hollow box, with several compartments in some species, corresponding to the carpels (see Fig. 18). This hollow box contains from one to very many of the tiny ovules, each of which may become a seed. As time goes on these ovules enlarge and the ovary also becomes larger. By the time the seeds are ripe the ovary has become the *fruit*. In the meantime the corolla and the calyx, as well as the stamens, have fallen off or shriveled away in most cases, so that most people never discover for themselves that one has anything to do with the other.

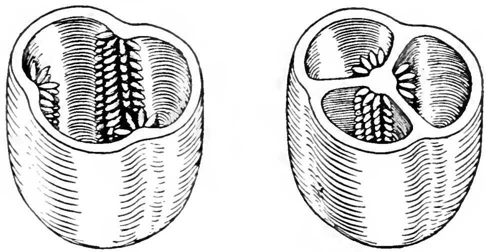


Fig. 18. Sections of ovaries

Ovaries are of many sizes and shapes. They contain but a single ovule in some species of plants, and in other species they bear hundreds. The ovules are definitely placed in one or more compartments of the ovary. Each compartment, with its style and stigma, is sometimes called a *carpel*

But the changing of ovules into seeds is not simply a matter of growth. Every farmer and gardener knows that it is possible to have plenty of flowers or blossoms with a very poor crop of fruit, even when the conditions for growth are of the best, and even though the plants are perfectly healthy.

35. Fertilization. Farmers and orchardists have known for many centuries that flowers will remain sterile (that is, they will fail to produce seed) unless some of the powdery **pollen** (*i*, Fig. 17) from the stamen somehow gets onto the stigma. This transfer of pollen was accordingly called fertilization, the idea being that the pollen makes the pistil *fertile*, or capable of bearing seed. But less than a hundred years ago the real facts about seed-making were discovered. When the pollen grain gets to the stigma, it absorbs some of the sirupy fluid on the latter. Then there begins to grow out of it a very thin thread, or tube,

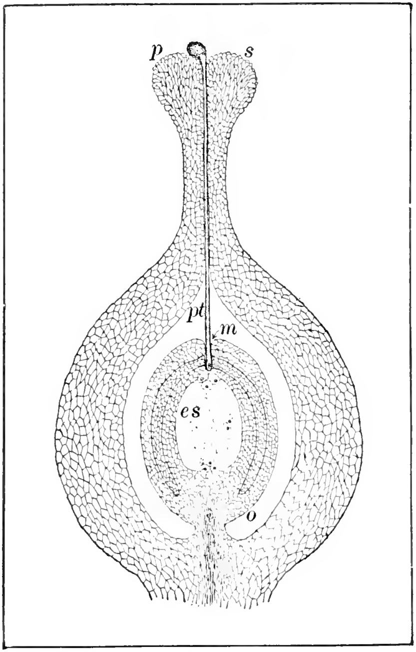


Fig. 19. Fertilization in a flower

When a pollen grain, *p*, alights on the moist surface of a stigma, *s*, it absorbs water and puts forth a thread of protoplasm, or a pollen tube, *pt*, which grows down the style into the ovary. The tip of the pollen tube finds its way to the inside of the ovule, *o*, through a small passageway, the micropyle, ***m***. The large cell in the middle of the ovule, called the embryo sac, *es*, undergoes a number of changes which result in producing several nuclei. One of these nuclei at the end nearest the micropyle corresponds to an egg cell. Similar divisions take place in the nucleus of the pollen grain, and one of the resulting nuclei corresponds to a sperm cell. The cell walls separating the pollen tube and the embryo sac dissolve, and the pollen nucleus unites with the egg nucleus. The newly formed joint nucleus, or fertilized egg, begins to divide. Thus it develops into a new plant, or embryo; the ovule containing it becomes a seed; the ovary becomes a fruit

which can be seen only with the microscope (see 7, Fig. 32). This pollen tube grows through the style and into the hollow of the ovary, then through a small hole in the ovule, the **micropyle**, which means "small gateway" (see *m*, Fig. 19). Finally it reaches the central space of the ovule, where there is a special mass of jellylike living stuff, the **embryo sac** (see *es*, Fig. 19). Here a portion of the matter in the pollen tube unites with a portion of the matter in the embryo sac, and from this united mass a new plant begins to develop. The uniting of the two masses of living matter is now called **fertilization**. This is the real act of reproduction, for its result is in fact a new individual (see Fig. 19).

36. Seed and fruit. After fertilization takes place the mass in the embryo sac absorbs food in large quantities from the parent plant and becomes

a baby plant, or **embryo**. The surrounding walls of the ovule become the seed coats. The ovule, with its embryo sac, thus changes into a seed. In addition to the food used by the embryo in its development and growth the parent plant supplies other food materials. These are accumulated either immediately around the embryo or within the embryo itself. After the seed sprouts and before it is able to supply itself the young plant uses this surplus food.

Fertilization brings about changes in other parts of the flower. The petals drop off, and usually the stamens also. The ovary begins to enlarge and at last ripens into the central or even the entire body of the fruit.[1] In some plants the calyx of the flower, and even the enlarged end of the stalk, the **receptacle**, may become fused into the fleshy fruit.

37. Pollenation. In many plants the pollen is carried from the stamen to the stigma by the growth movements of the parts of the flower. The style, as it gets longer, may bring the stigma into contact with the anther; or the corolla, as it grows and opens, pushes the stamen against the stigma; or the stalk of the flower may bend over as it grows, and so deposit some of the pollen from the anther on the stigma. In some flowers the anther stands above the stigma, and the pollen is carried over by the action of gravity. Thus there are many kinds of plants in which the flower may be said to pollenate itself. This process is sometimes called *close-pollenation*. There are many plants, however, in which close-pollenation is quite impossible.

1. *Space relations*. The position of the stamen in relation to the pistil may make close-pollenation impossible, as in the iris, or blue flag, in the milkweed, in all the orchids, and in many other groups of plants. In some species there are two kinds of

[1] In most of the common plants the fruit will not ripen (that is, the ovary will not continue its development) unless fertilization takes place. But there are many plants in which a seedless fruit is possible. Seedless oranges, seedless apples, seedless grapes, the pineapple, and the banana are examples of fruits that develop without the ovule being first fertilized. The plantain and the breadfruit develop a more juicy fruit when there is no fertilization.

flowers, some bearing only stamens and others bearing only pistils, as the corn and other grasses, birch, hazel, chestnut, oak, squash, and the cone-bearing trees. Such plants are sometimes called *monœcious*, meaning "of one household." It is of course impossible for close-pollenation to take place in these.

There are still other plants in which the stamen-bearing flowers are borne on one individual and the pistil flowers on a different one, as in poplar, willow, box elder, tape grass (*Vallisneria*) (see Fig. 20), begonia,

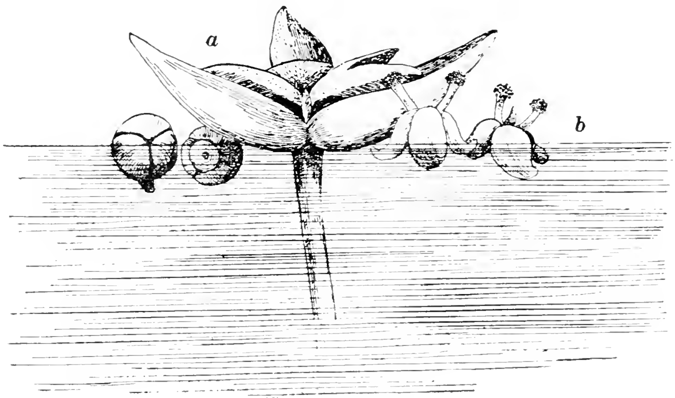


Fig. 20. Pollenation by water

The tape grass (*Vallisneria*) is a diœcious water plant. The pistillate individual grows up to the surface of the water, where the flowers, *a*, are opened, while the staminate individual remains beneath the surface. The staminate flowers, *b*, are detached from the stalks and rise to the surface, where they float about and gather in large numbers in the quiet stretches of water close to solid objects of various kinds. Whenever one of these floating stamen flowers comes close to the pistillate flower of the species, the anther is brought into direct contact with the stigma, and in this way pollenation is effected

sassafras, and virgin's bower (*Clematis*). Such plants are sometimes called *diœcious*, meaning "of two households." Close-pollenation must be impossible in these plants also.

2. *Time relations.* In some species of plants the stamens and the stigmas do not ripen at the same time, close-pollenation being thus impossible.

The pollen ripens before the stigma in maize, in the mallows, in many species of the aster family, in the creeping crowfoot, and in the sage.

The stigmas ripen ahead of the stamens in the common plantain, in the potentilla, or cinquefoil, and in the Oriental grass known as Job's tears.

3. *Physiological relations.* In some species of plants it is found that if the pollen gets from the stamen to the stigma of the same flower, the pollen will not lead to fertilization. In buckwheat, in most orchids, in certain species of day lily, and in some members of the bean family the pollen will not even put out a tube if placed on the stigma of the same flower.

There are, then, many species of plants in which close-pollenation cannot take place, or in which it is not very effective if it does take place. How, then, do these plants produce seeds, or, rather, how do they secure pollenation? In other words, how is pollen carried from flower to flower?

38. Cross-pollenation. Plants that cannot pollenate themselves simply depend upon outside moving bodies or moving forces to transfer the pollen for them.

1. *Wind pollenation.* The most common moving agency that acts between plant and plant is the wind. The dryness and abundance of the pollen produced by many of the common trees, and the presence of pollen in the dust at certain seasons of the year, would make us suspect that the wind must distribute a great deal of pollen (see Fig. 21).

2. *Water pollenation.* Another agent that is effective in distributing pollen for plants is water. This is of course limited to plants that live in the water (see Fig. 20).

3. *Bird pollenation.* Next to the wind the most common moving agents that go from flower to flower are flying animals, like birds and insects. We know that not all birds or all insects can serve plants as pollen carriers, but only those that do regularly visit flowers (see Fig. 22).

4. *Insect pollenation.* There are hundreds of species of plants whose flowers are pollenated by insects, chiefly those of the bee order and of the butterfly and moth order. All these insects have sucking mouths, and many of them visit flowers that con-

tain nectar. Some of these insects also use pollen as food. The bees, for example, feed quantities of pollen to the young in their hives. In getting pollen or nectar the insect rubs off pollen on various parts of its body. Later, when it visits another flower of the same kind, the pollen is rubbed off against the stigma (see Fig. 23).

39. Adaptations in flowers. Wherever we see a living thing we cannot help being impressed by the "fitness" of its parts and of its activities. The organs and functions are beautifully related to one another as members of the organism, and they are beautifully related to the surroundings, making life possible. Thus in the flowers we may see the wonderfully delicate structures bearing pollen and ovules. Many flowers close toward sunset and open again at dawn, exposing the anthers and stigmas to insects by day but protecting them at night. The various colors in the corolla, the odors, the nectar, all very evidently attract insect visitors. The curious shapes match almost perfectly the sizes and shapes of particular insects. The stigma is rough, or hairy, or sticky, just right for catching pollen, and bears the fluid in which the pollen sprouts out the pollen tube. Inside the style there is a hollow passage or a spongy structure through which the pollen tube readily works its way. The pollen tube's irritability guides it toward the ovule. In the ovule is the micropyle, through which the pollen tube finds its way to the embryo sac. And we could go on multiplying illustrations of the remarkable adaptation of part to part and of all to the conditions surrounding the plant. Of course the same may be said of the many details that make

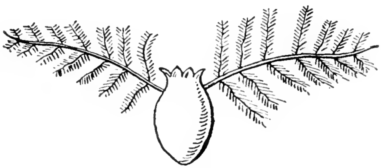


Fig. 21. Stigma of a grass

In wind-pollenated plants the stigmas usually expose a large surface to the wind. A study of conditions on farms that produce corn, wheat, oats, and other grains shows that these plants, as well as many others, depend entirely upon the wind for their pollenation. Indeed, it is sometimes necessary to take special precautions to prevent the wind from bringing to a group of plants an undesirable kind of pollen from a remote field

up the structure and activities of the various insects that visit the flowers. While it is true that in order to be alive the activities of an organism must fit the surrounding conditions, it would be a mistake to suppose that *every* structure and *every* character and *every* activity is of value in keeping the organism alive. There are many plants that have colored corollas (some kinds of beans, for example) but that do not depend upon insect visitors at all, and there are other plants that receive insect visitors without being particularly showy. Again, while there are many insects that help in pollenation when they come for nectar, there are certain plants that yield nectar without getting any use from the visits of the insects. For example, nectar is sometimes formed on the stems and leaves of various plants, including ferns (which produce no seeds at all).

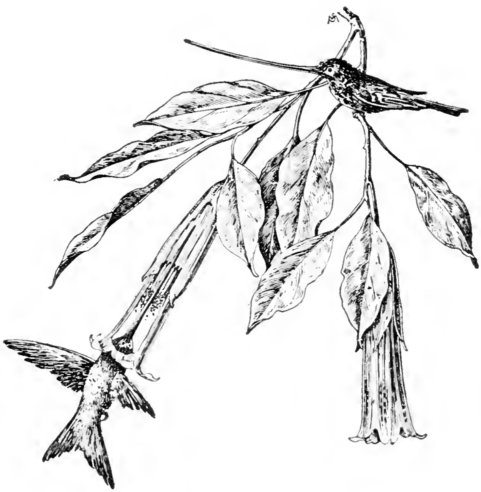


Fig. 22. Pollenation by birds

The saber-billed humming bird visits certain large flowers and laps up the sugary fluid, or nectar, and so rubs off some of the pollen. When it visits another flower, this pollen comes off onto the stigma. Certain tropical flowers are said to be pollenated by bats that come to them for nectar. (From an exhibit in the American Museum of Natural History, New York)

40. Interdependence. In some cases the dependence between insects and flowers is so great that it has an important bearing on the practice of plant raisers. A poor supply of blossoms may mean a poor honey crop and fewer bees the following season. The lack of bees to pollenate the blossoms may mean a poor fruit crop.

When plants are transferred from one part of the world to another, it sometimes happens that they fail to bear seeds because the particular insect upon which they depend is absent in the new region. This was the case when vanilla culture was extended from Mexico and South America to various islands in the Indian Ocean. Here the plants grew luxuriantly and bore many flowers, but ripened no pods, or "beans" (for which the plants are raised), because the insect necessary for pollenation was not present (see Fig. 24).

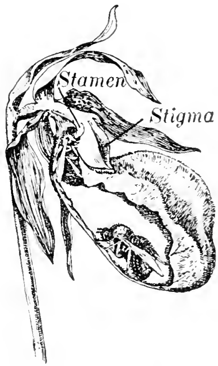


Fig. 23. Pollenation by insects

In the lady's slipper and in many other flowers, insects alighting on the corolla crawl into the interior, guided by the form and the markings. In many flowers the arrangement of the parts is such that the insect must brush against the stigma in going in, and against the anthers in passing out. As a result the animal carries pollen from flower to flower. Many species of plants, especially among the orchids, depend upon single species of insects for their pollenation

When fig trees were first introduced into California they produced large, juicy fruit; but they did not dry properly and could not be prepared for shipping. To get the normal fruit it was necessary to find the insect that brings about pollenation. This little wasp has a curious life history which is closely tied up with the fig plant. The wasp cannot complete its life cycle except with the aid of the fig; the fig cannot complete its life cycle except with the aid of the wasp.

A living thing cannot live by itself alone, or at least not completely. In general, all animals depend upon plants for their means of life, and many plants depend directly upon animals. But there seems to be no advantage in being so dependent upon some particular plant or animal as to be unable to live without it (see section 27). Plants that are not so highly specialized, depending upon the wind for pollenation, seem to be at least as well off, or at least many are quite as capable of reaching to all parts of the earth—for example, the grasses, the

cone-bearing trees, and the catkin-bearing trees.

41. Homology and analogy in the flower. If you have studied several different kinds of flowers, you must have noticed the very great differences among petals of different species or among pistils. Indeed, you will often have some difficulty in making up your mind whether some particular structure is one of the regular parts of a flower or something totally different. A part of the fascination that many people find in studying new varieties of wild flowers is that of recognizing familiar structures under strange disguises, or like that of solving puzzles. Stamens may be large or small, with long filaments or with none, standing freely or fused with one another or with the corolla. Similar modifications are found in the other parts. Some students of plant life go even farther and point out that stamens and carpels, as well as petals and sepals, are special kinds of leaves (see Fig. 25,

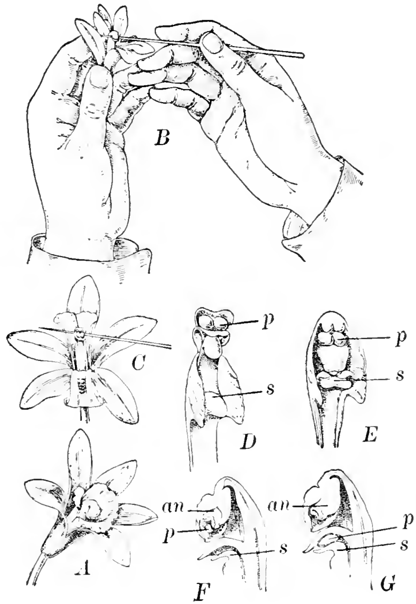


Fig. 24. Hand pollenation in the vanilla flower

Instead of importing the needed insect to carry on pollenation, the raisers of vanilla decided to hire women and children to go from flower to flower and pollenate by hand. In the orchids the stamens are fused with the stigma, placing the anthers above the stigma in such a way as to make self-pollenation absolutely impossible. *an*, anther; *p*, pollen masses; *s*, stigma. *A*, general view of flower; *B*, position of hands and needle in artificial pollenation; *C*, needle lifting pollen masses; *D*, anther raised to expose pollen masses; *E*, style raised to show opening in stigma; *F*, longitudinal section to show relative positions of anther and stigma; *G*, longitudinal section after pollenation, showing pollen masses in the stigma. All the vanilla beans in the Seychelles Islands are grown with hand pollenation

and 5, Fig. 197). All the various structures that we may consider as having the same kind of origin (in this case, outgrowths from the stem) and the same fundamental structure (in this case, a more or less flattened structure with nerves running through it) are said to be *homologous* (see section 28).

Nearly every beginner in the study of flowers is deceived by the daisy and the dandelion, of the sunflower family, because these plants have structures that are *analogous* (see section 29) to those we have already studied, but not homologous. In this family of plants the flowers are very small, but many of them are clustered in a *head*, so that we commonly speak of the whole head of a hundred or more flowers as *a flower*. Certainly a head has the general appearance of a flower, and we may consider it analogous to a flower since, like a larger corolla, it attracts insects, as in the daisy or the sunflower, where the small flowers around the outer edge of the head have elongated or strap-shaped corollas that are sometimes mistaken for single petals (see Fig. 184).

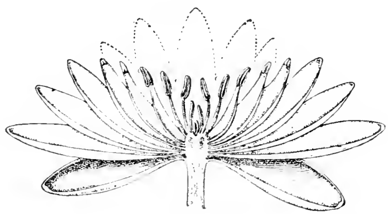


Fig. 25. Homology in the structure of a flower

In the water lily (as well as in the peony and some other flowers) it is possible to see that the stamen may be considered as a special kind of leaf. There is a gradual passing from sepal to petal, and as we pass toward the center of the flower some of the structures become less and less like "leaves," and more and more narrow, until they are definitely stamens, made up of the stalklike filament and the distinct anther

At the base of the head are many small, leaflike structures which we may consider analogous to a calyx. This structure is called an **involucre**, and the single leaves are called **bracts.** In the Jack-in-the-pulpit and the calla lily (both of the *Arum* family, not lilies) many tiny flowers are arranged on a spike, and a very large bract, sometimes mistaken for a corolla, surrounds the whole (see Fig. 26). In the dogwood the four large white or pinkish "petals" are really bracts. Thus we see that in plants as well as in animals a structure carries on the func-

tion that normally belongs to a different organ, and that one organ may take on a variety of functions.

42. Conservation of wild flowers. People are coming to have more time for recreation, and it is becoming easier to get into the woods and unoccupied spaces. As a result more and more people are tempted to gather wild flowers because of their beauty and interest. There has actually been a serious reduction in many species. Many of our native plants have been almost entirely exterminated, and others are going fast in certain parts of the country. The trillium, or wake-robin, of which there are several species, is almost unknown in regions where it was very plentiful a dozen or twenty years ago. The same is true of the dogtooth violet and of the clintonia, and of many native orchids. The dogwood is so conspicuous in the spring that hiking parties and automobile tourists are tempted to carry away large quantities of the blossom-bearing branches.

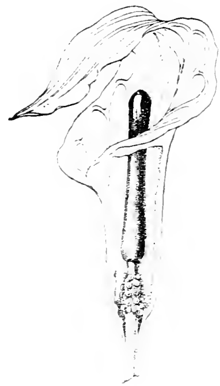


Fig. 26. Jack-in-the-pulpit

In plants of this family there are two kinds of flowers, the pistil-bearing and the stamen-bearing. Both are found growing in clusters on the same stalk, the pistil flowers near the base and the stamen flowers toward the end. A large, leaflike organ, the *spathe*, almost incloses the spike bearing the flowers

Those of us who value beauty in nature (which includes, of course, the colors of flowers and the songs of birds), and who realize the importance of preserving it for as many as possible to enjoy, will do all we can to protect from wanton destruction or wasteful collection the wild flowers that we still have with us. We can all get more enjoyment by leaving them in their natural surroundings. For collecting or scientific study we can usually get enough by means of photographs and notes and sketches. For the study of structure we can use either cultivated plants or weeds, the destruction of which will do the community more good than harm.

There has been developing an interest in propagating wild flowers by means of seeds planted in suitable places. Protected from careless pleasure seekers, plants can in this way be made to cover unused spots, and some of the rarer varieties may be preserved from extermination. This seems to be a good plan to follow in many parts of the country, and is worth helping.

THE CYCLE OF LIFE: FLOWERS

1. Reproduction (what it means)
    - Related to the beginning of life
    - Related to the end of life
2. Structure of flowers
    - The floral envelope
        - The calyx — (sepals); the corolla — (petals)
    - Essential organs
        - Stamens
            - Anther — (pollen)
            - Filament
        - Carpels — (pistil)
            - Ovary — (ovule)
            - Stigma
            - Style
3. Pollenation (meaning)
    - Close-pollenation and cross-pollenation
    - Agencies of cross-pollenation
        - Wind; insects; water; birds
4. Origin of new plant
    - Fertilization
        - Pollen tube; embryo sac; fusion
    - Growth of seed
        - Fertilized embryo sac becomes embryo
        - Ovule becomes seed
    - Ripening of seed
        - Ovary becomes seed-bearer (fruit)
5. Interdependence between insects and flowers
6. Homologous parts of flowers
7. Analogies in composite and other clusters of flowers
8. Conservation of wild flowers
    - Spare; protect; propagate

QUESTIONS

1. Supposing that everything else about organisms remained the same, what would happen if every plant and every animal suddenly became incapable of dying?

2. How does a baby plant originate? How does it get nourishment?

3. How can plants be multiplied without the use of seeds?

4. How is pollenation brought about in each of ten plants that you have observed?

5. How does the living matter in the pollen grain reach the living matter in the embryo sac?

6. What are the advantages or disadvantages of having a very long style (as in the Indian corn, for example), compared to having a very short style (as in the buttercup)?

7. In the flowers that you have studied, what distinguishes those with more division of labor from those with less division of labor?

8. Many common flowers have their parts in fours or fives; others have their parts in threes. Can you find any other peculiarities of the plants in one group or the other?

9. What are the advantages of keeping bees in the neighborhood of farms and orchards?

10. Why do plants that are brought to a new region, with suitable soil and climate, sometimes grow very well but fail to produce fruit?

11. In what ways is an involucre like a calyx? In what ways is it different? What is the nature of the rays on a sunflower?

REFERENCE READINGS

Bergen and Caldwell. Practical Botany, chap. vii, Flowers; chap. viii, Pollination and Fertilization.

Osterhout, W. J. V. Experiments with Plants, chap. vi, The Work of Flowers.

Gaye, Selina. The World's Great Farm (extract in C. H. Ward's "Exploring Nature," pp. 74–75).

Lubbock, John. Flowers, Fruits, and Leaves (extract in C. H. Ward's "Exploring Nature," pp. 79–87).

Weed, Clarence. Ten New England Blossoms.

Any manual or field book for identifying the common plants by their flowers.

CHAPTER V

LIVING MATTER

Questions. 1. Does life come from one particular part of the body, like the heart or the blood, or is it in all parts? **2.** Why can some parts of an organism be destroyed without killing the body, whereas it does kill the body to destroy other parts? **3.** What is the smallest portion of a plant or animal that can remain alive? **4.** What are the smallest plants or animals? **5.** Are there any living things too small to be seen?

43. Protoplasm. A man has none of the organs that a tree has; a tree has none of the organs that a man has. Indeed, animals differ so much from plants that it is difficult at first to see how they can be so much alike in those three qualities (growth, movement, and irritability) which distinguish living things from non-living things. The solution to this difficulty is found in the fact that the bodies of all organisms are made up of a peculiar substance (or rather a *mixture* of substances) which seems to have all the qualities of living bodies. This is the stuff in living things that can grow; this is the stuff that moves; this is the stuff that is irritable.

The microscope shows this living stuff to be a slimy, or jelly-like, substance something like the white of egg in appearance. Under a more powerful microscope it sometimes appears to have many minute bubbles in it or to consist of an extremely fine network. This stuff is called **protoplasm** (*protos*, first; *plasma*, forming material), and in all essential respects it seems to be alike in all plants as well as in all animals. It is the protoplasm of a plant or of a kitten that grows. It is protoplasm in the body of the Venus's-flytrap or of a snake that moves when the organism springs upon its victim. It is the protoplasm of the geranium or of the worm that is sensitive to light.

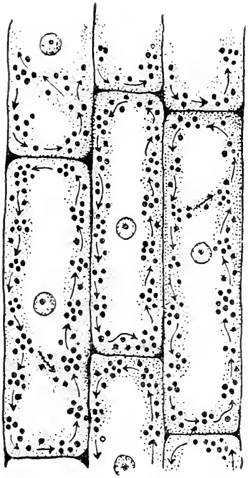


Fig. 27. Protoplasm moves

The arrows indicate the streaming of the protoplasm within the cells

44. The body and protoplasm. Most of the plants and animals that we know do not look a bit slimy. The protoplasm does not appear on the surface of most organisms. Even when you cut your finger or pluck a flower you do not expose protoplasm so that you can see it. Indeed, protoplasm very rarely occurs in masses large enough to be seen by the unaided eye. Yet in the course of its growth it builds up the enormous bulk of the elephant or of the massive "big trees" of California.

45. Cells. From the latter part of the seventeenth century, when the microscope was first able to show such small structures, we have known that the body of every plant and every animal is made up of a number of tiny compartments called **cells**. This name was suggested by the resemblance of a mass seen under the microscope to the cells, or chambers, of a honeycomb. During

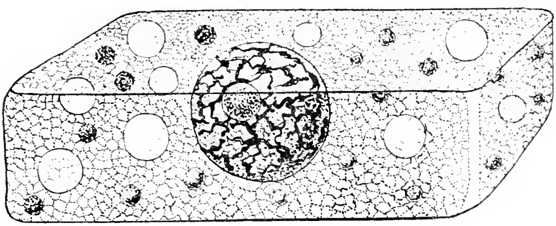


Fig. 28. Diagram of a cell

The mass of the cell content consists of the protoplasmic network, with the coarser-grained nucleus. Within the protoplasm are more solid bodies, and droplets of more liquid substances

the past hundred years it has been found that the living contents of a cell is protoplasm. When we look at an organism

we see, not the protoplasm, but the *walls* of millions of these cells. In the larger plants and animals the outer layers of cells are usually dead; that is, the protoplasm is no longer present, only the dead walls remaining. This is true, for instance, of our own skin, of the bark of trees, or of the hide of the horse.

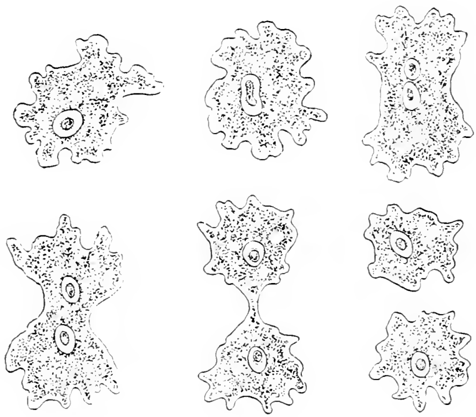


Fig. 29. The one-celled animal, ameba

The ameba has no definite shape, but moves about, pushing its jellylike mass now in one direction, now in another. After reaching its full growth the *nucleus*, or kernel, lengthens out and gradually divides into two parts. The rest of the animal's body also lengthens, and the two ends seem to move slowly away from each other until there are two distinct individuals. Each of these is as complete as the other, and both are the same as the mother cell except for size

The microscope enables us to see the forms of many kinds of cells taken from the bodies of plants and animals. Cells are different from each other not merely in size but in shape as well. Some cells have thicker walls, some have thinner walls. Some seem to have various kinds of solid bodies floating about within the wall; others have a very few or none of these. Some have smaller and some larger bubbles of clearer liquid.

In some plant cells the protoplasm can be seen to move about. This movement, always present in live protoplasm, is easily seen in the cells of certain water plants (Fig. 27).

46. Nucleus. One special portion of the protoplasm deserves particular notice. Near the center, or at one side, we can generally find a portion that seems to be denser than the rest. This is called the kernel, or **nucleus.** Since the protoplasm is transparent, it may be difficult to distinguish the parts in many

plant and animal cells. It has been found convenient to stain masses of cells with various kinds of pigments or dyes, to make the structure stand out more distinctly under the microscope. When certain dyes are used, the nucleus becomes particularly distinct, since it absorbs these dyes more readily than do other parts of the cells, and within the nucleus we can sometimes see fine little rods or strands (Fig. 28).

47. Numbers of cells. Most plants and animals that you have seen probably have indefinite numbers of cells, and these run into countless millions. Some living things, however, have a very definite and limited number of cells.

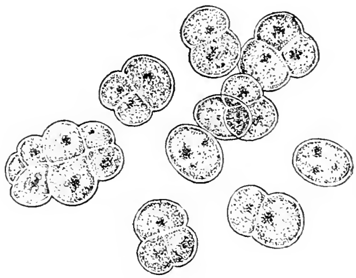


Fig. 30. Green slime. ($\times 500$)

This plant consists of a single cell. When the cell divides into two, the daughter cells may cling together or they may be separated. Sometimes a cluster, or "colony," is formed, containing many cells; in such a cluster each cell is independent of the others, since each is capable of making its own food as well as of absorbing the raw materials from the environment

One of the simplest animals is the one-celled *ameba*, which lives in stagnant pools and other wet situations. Under the microscope it appears to be an irregular lump of jellylike matter, in which various granules and bubbles can be made out. There is a nucleus, and all around it movements are constantly taking place. The shape of the mass of naked protoplasm is constantly changing, resulting in sluggish movements of the animal. The slimy mass swallows particles that may serve as food, and it crawls away from contained particles that are no longer of service. The animal is sensitive to physical and chemical forces in the environment, and responds to disturbances by contractions of the protoplasm (Fig. 29).

In many species of plants each individual consists of a single cell. The bacteria, of which everybody hears a great deal, are one-celled plants. The "green slime," which lives on the shady side of trees or on damp shingles, is another one-celled plant.

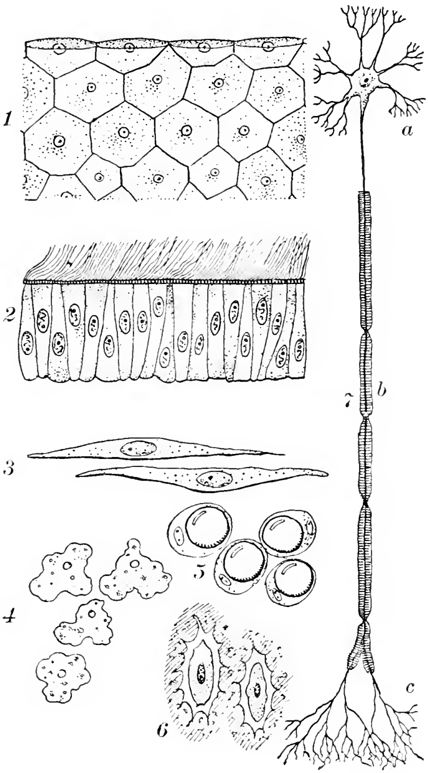


Fig. 31. Various kinds of animal cells

1, flat epithelial cells, like those lining the cavity of the abdomen in man and other animals; *2*, columnar epithelial cells, like those lining the air passages, with hairlike projections of protoplasm, called *cilia*; *3*, muscle cells, unstriped, like those in the walls of the intestine and of blood vessels; *4*, shapeless cells of naked protoplasm, like those of Ameba or of white blood corpuscles; *5*, cells containing fat globules, like those in adipose tissue; *6*, bone cells surrounded by hard deposits of limy material; *7*, a nerve cell, or *neuron* (*a*, the cell body with its branching outgrowths, or *dendrites*; *b*, the longest outgrowth, the *axon*, ending in *c*, the terminal branches). Each cell shows a distinct nucleus

48. Division of cells. Every living thing has a beginning as well as an end. Among the one-celled plants and animals a new individual originates by the division of the parent cell; or rather two individuals originate in this way (see Fig. 30). Every larger plant or animal, consisting of very many or many millions of cells, also originates as a single cell (see section 35). The fertilized egg cell divides into two cells; each of these divides again; and so on (see Fig. 107). As the cells remain clinging to each other, the whole mass increases in size.

The division of the cell, whether it is a fertilized egg cell, or a one-celled organism, or one of the many cells making up a larger plant or animal, takes place in very much the same way in all cases. The nucleus divides first, the little rods

separating into two equal groups. Then a new wall is formed between the two new kernels. In the case of the ameba, the two halves of the naked protoplasm crawl away from each other and finally separate (Fig. 29).

49. Tissues. In plants and animals large enough to be seen without a microscope there are usually many different kinds of cells. Masses of similar cells together make up a **tissue.** In our own bodies there are skin tissue, muscle tissue, brain tissue, bone tissue, gland tissue, connective tissue, and others. In the body of an ordinary plant we may recognize bark cells, wood cells, pith cells, skin cells, and other tissue groups (see Figs. 31, 32). Each of the organs, such as hand or eye, flower or fruit, is made up usually of several kinds of tissue. The hand, for example, has in it every main class of tissue that is to be found in the human body. In the twig of a tree we can find pith, wood, bark, epidermis, and so on.

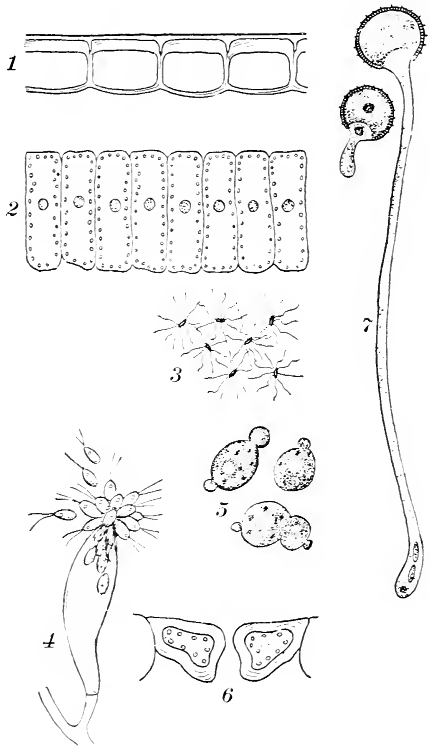


Fig. 32. Various kinds of plant cells

1, epidermal, or skin, cells of a leaf, showing the outer wall greatly thickened, and the *cuticle*; *2*, columnar cells, like those of the palisade layer of a leaf pulp; *3*, moving ciliated cells, like those of typhoid bacilli; *4*, swimming spores of a water mold; *5*, budding cells, like those of the yeast plant; *6*, guard cells inclosing a breathing hole, or *stomate*, on the surface of a leaf; *7*, a pollen tube growing out of a pollen grain

50. Protoplasm fundamental. Protoplasm has been called the physical basis of life; it is well named the first, or basic, material. As we have seen, in the one-celled ameba (and in other one-celled animals, as well as in one-celled plants) the single bit of protoplasm carries on all the life activities—growth, movement, reproduction, etc. Yet in the larger plants and animals (those having several kinds of cells and millions of each kind) the *protoplasm of every cell carries on the same fundamental activities.* However different a bone cell may be from a brain cell, for example, or a root-hair cell from a blood cell, the protoplasm in all cases is *irritable*, it is capable of *growth*, it shows some *movement*, and at least at some stage in its life it is capable of *reproduction.*

The many kinds of organisms, with peculiar forms and organs, and the many different kinds of activities that are a constant source of wonder arise apparently from the fact that protoplasm, always the same in some respects, is yet always capable of changing its manner of living as circumstances change. Fundamentally always the same, in every particular case it is distinct or peculiar; this is characteristic of protoplasm, as it is characteristic of life.

LIVING MATTER

1. Protoplasm
    - Appearance
    - Structure
    - Importance
    - Qualities
        - Irritability
        - Assimilation
        - Movement
2. Cells
    - Where found
    - Structure
        - Plasma
        - Nucleus
        - Wall
    - Kinds
        - One-celled plants
        - One-celled animals
        - Plant tissues
        - Animal tissues
3. Cell division
    - Stages in cell division
    - Cell division in one-celled plants
    - Cell division in one-celled animals
    - Cell division in many-celled organisms
    - Relation to growth
    - Relation to reproduction

QUESTIONS

1. In what parts of your body is there growth? In what parts of the tree's body?

2. In what parts of your body is there movement? In what parts of the tree's body?

3. In what parts of your body is there irritability? In what parts of the tree's body?

4. How is division of labor to be seen in your body? in the trees?

5. How is adaptation to be seen in your body? in the tree's body?

6. What makes possible these similarities between two things that are so different from each other as are a human body and a tree?

7. What makes possible all the difference that we see between two different kinds of organisms?

8. How does protoplasm resemble the white of an egg? How does it differ from the white of an egg?

9. How does a one-celled organism multiply itself?

10. How does the one-celled stage of a bean plant become a many-celled bean plant?

11. How do the results of cell division in a one-celled organism differ from the results of cell division in a many-celled organism?

12. Why can we not see the protoplasm of common living things?

13. What parts of your body are not alive? What is the source of these non-living parts?

14. How do different kinds of cells differ from each other?

15. What different kinds of tissue can you recognize in a plant without the use of a microscope? What kinds in an animal?

REFERENCE READINGS

HOUGH and SEDGWICK. The Human Mechanism, pp. 43–47.

WILSON, E. B. The Cell, pp. 17–30 (extract in C. H. Ward's "Exploring Nature," pp. 190–197).

HUXLEY, T. H. Methods and Results, Essay 3, The Physical Basis of Life.

DENSMORE, H. D. General Botany, chap. iii, The Cellular Structure of Plants; chap. iv, Historical Sketch of the Cell and the Cell Theory.

COCKERELL, T. D. A. Zoölogy, chap. ii, The Living Substance; chap. iii, The Cell and its Activities.

CHAPTER VI

LIVING CONDITIONS; THE SEED

Questions. 1. What makes seeds sprout? 2. How do plants and animals remain alive while inactive during the winter? 3. Can seeds sprout without soil? 4. Can plants live without soil? 5. Why are seeds killed if they are allowed to become damp? 6. Why does salt water kill some seeds? 7. What is necessary for all living things? 8. Why do not fish drown in the water? 9. Why cannot fish live out of water?

51. All life dependent. Fishes live only in water; the trap-door spider and the horned toad (which is not a toad at all, but a lizard) are found only in the desert. The butterfly is a creature of air and sunshine, but the tapeworm is at home in the dark recesses of a little boy's intestines. The green slime seems to thrive on the bark of a tree, but nothing less than the inside of a blood cell will serve for the malaria plasmodium. Reindeer moss (really a kind of lichen) will live under the snows of Iceland, but the banana plant finds the winters of Florida too severe. Protoplasm is truly wonderful, since *it can live under all these different conditions.* What conditions are really *essential* to life? Is it not rather true that we find a different kind of life in each set of circumstances?

52. Awakening life. In winter most of the plants of the preceding season are dead. Of those that are not dead most are either bare of all foliage or reduced to some kind of resting state. There are roots and stems lying dormant (sleeping) underground. There are millions of seeds that look as lifeless as pebbles until circumstances favorable to life activity appear. In general, similar facts may be observed regarding animals.

53. Sprouting of seeds. Seeds of many different kinds are kept in boxes or jars for months at a stretch, or even for years, and there is no sign that any of them have sprouted. The gar-

dener or farmer places his seeds in the ground, and they sprout. Should we conclude that the *soil* somehow causes the seeds to begin their active growth after their long rest? The soil is a mixture of many kinds of stuff, some of which may have something to do with the sprouting. But others of them may have nothing at all to do with it. To find out just what it is that causes the sprouting we must consider the effect of *each* of the various factors of the seed's surroundings by itself.

54. The environment. Now, in what ways do the conditions surrounding a seed in the ground differ from the conditions in a box or a jar? There may be a difference as to *temperature*, or as to the *air*, or as to the amount of *water*, or as to the *light*, or as to some of the *chemical* substances present in the soil. Experiments have been made with every one of these factors. We can also answer this question in part from our experience.

Most of us know that seeds kept in jars will not sprout, whether they are kept in the dark or exposed to light. Putting seeds in the ground brings about their germination *not* on account of darkness but on account of some other factor. We also know that seeds kept in a warm place and seeds kept in a cool place will both fail to sprout so long as they remain in our jars or boxes. The soil may be cooler than our storeroom, or it may be warmer; but it is not *this* that makes them sprout in the ground. Perhaps the soil keeps some of the air away from the seed; but keeping air out of the jar will not make the seeds sprout. So it cannot be the absence of air by itself, or the presence of air by itself, that causes the seeds in the ground to germinate.

In regard to the chemical substances in the soil, our usual experience tells us nothing at all. Are there certain substances that cause the sprouting? We might find out by trying some of them. The chemist can tell us what there is in the soil, and he can also prepare the different kinds of stuff in a pure condition; but if we place the seeds in boxes containing the various ingredients of the soil, such as sand, clay, and various salts, we shall find that not one of the seeds sprouts. This suggests that

the one or many substances which might perhaps cause sprouting *cannot get into the seeds* in the dry state. We should therefore try these substances with water. That, however, at once raises the question, Has water by itself any effect on the sprouting seeds? We should therefore proceed to experiment with pure water.

55. Relation of water to sprouting. We may place a number of seeds in each of several vessels with various quantities of water, while other seeds from the same lot are kept under similar conditions of air, light, and temperature but without water. The results should convince us that one of the conditions necessary for starting the germination of the seeds is the presence of a certain amount of water.

We shall find also that some kinds of seeds will fail to sprout if they are completely covered with water, although other kinds will sprout under water. The seeds in the first class are not injured by water; the liquid simply prevents them from absorbing sufficient quantities of air.

56. Relation of temperature. It may be that other factors also play a part. For example, seeds in the presence of water may sprout at one temperature but not at another. From actual experience with seeds of different species of plants we know that some kinds may be safely sown earlier in the spring than others. From experiments we can also learn that some seeds will fail to sprout when it is too cold or too warm. A systematic experiment in which several groups of seeds with water are placed so that each set is in a different temperature will satisfy us (1) that there is a point at which the sprouting proceeds most quickly, and (2) that there is a limit in the range of temperature for the sprouting of every species of seed.

57. Relation of air. Is the presence of water at a favorable temperature not enough by itself to cause the seeds to sprout? The air may perhaps influence the activity of the young plant after water is absorbed. Experiments can show us whether air is necessary for sprouting in addition to water. In the same way we can go on and try out the possible influence of light.

58. The seed. We may know something about the conditions that are necessary for the sprouting of seeds, and still be unable to answer the question, Why do seeds sprout? A part of the answer is, of course, in the nature of the seed itself.

We have already seen that a seed originates in a flower (sect. 36). If you examine the outside of any seed, you can usually find a scar that was left when the seed broke away from the little stalk by which it was fastened inside the ovary, or fruit. Very often you can also see the tiny hole (the *micropyle*, see *m*, Fig. 19) through which the pollen tube found its way to the embryo sac. The seed may absorb water through this hole, but it does not seem to be of any importance after the seed is ripe. The coat of the seed, which in some cases has more than one layer, is evidently a protective cover. In many plants, however, the protection is furnished by the fruit wall—in common nuts, for example. After you remove the coat you can find the part of the seed that is really important in the life of the plant. In fact, you will find here a young plant, or **embryo**, so that we may say that *a seed is an embryo with its covering*.

59. The embryo. If you recall that ordinarily we think of a whole plant as being made up of root and shoot (see Fig. 5), you can soon see that the embryo is indeed such a plant. After soaking some seeds of pumpkin, beans, peanuts, and other species in water, so that you can easily open them up and take them apart, you will find two fleshy parts that make up the bulk of the embryo. These are really special kinds of leaves, although they do not resemble the ordinary leaves of these plants. Now bend them aside carefully without breaking them off, and you will see that they are attached to a short, stalklike piece. One end of this rod tapers to a point; the tip of this corresponds to the root, although it does not branch. The rest of the main stalk, with its two large outgrowths, corresponds to the shoot. The upper end of this may be enlarged to a little knob or bud. In the embryo of the bean you can make out two small but distinct leaves overlapping a tiny bud.

The fleshy leaves are called seed leaves, or **cotyledons**. The part below the meeting point is the **hypocotyl** ("below the cotyledon"). The part above is called the plumule or first bud, or the **epicotyl** ("above the cotyledon") (Fig. 33).

Although the cotyledons do really correspond to leaves, there are many plants in which they never come out of the ground, as in the pea. In other plants the cotyledons do get above the earth but do not spread out or become green, as in the bean.

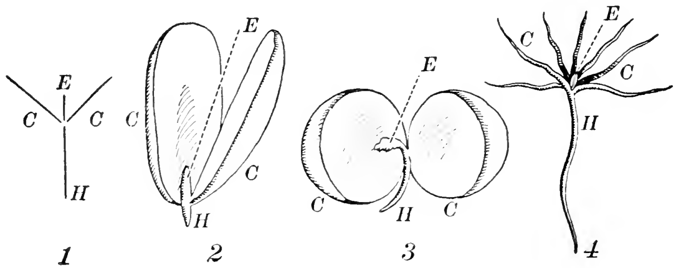


Fig. 33. Embryos of plants

1, diagram showing relative positions of the parts of the embryo; *2*, embryo of peanut; *3*, embryo of pea; *4*, embryo of pine; *C, C*, cotyledons; *E*, epicotyl; *H*, hypocotyl

When we compare the embryo of a grain, such as the corn, with the other embryos that have been mentioned, we find one great difference in the structure. The grain has but *a single cotyledon*. This is rather large, though not fleshy, and remains in contact with the endosperm and serves as an absorbing organ, withdrawing food material from endosperm and transferring it to the growing plant (see *4*, Fig. 34).

Many plants besides the grains have but one cotyledon in the seed. This fact may not be of any great importance by itself, but it is connected with so many other characters (such as the veins in the leaves, the structure of the stem, the structure of the flower, and general habits of life) that we sometimes designate one of the main divisions of seed-bearing plants as the *monocotyls*, meaning the "one-cotyls," and another as the *dicotyls*, or "two-cotyledon plants." The latter includes most common weeds and cultivated plants except the grains.

Seeds of the plants in the pine family (fir, spruce, hemlock, etc.) have usually several cotyledons, and this family is accordingly called ***polycotyls***, meaning "plants having many cotyledons" (see *4*, Fig. 33).

60. Food in seeds. The concentrated food found in seeds of common plants is of interest to us in three ways: First of all, we may infer that this food is actually used by the young plant until it is able to provide for itself. That this is a sound inference may be tested by separating from several seedlings the "food reserve." Next we can observe that the cotyledons in such plants as the beans and peas do actually shrivel away as the plant becomes larger. The contents of the corn grain also disappear as the seedling develops. Finally, by means of chemical experiments we can see that the changes taking place in the food masses of the seedlings are of the kind that we should expect to find if the food were actually being transported to the growing portions (see section 105).

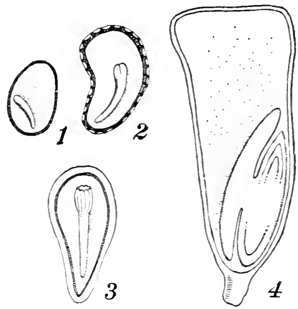


Fig. 34. Seeds with endosperms

1, asparagus; *2*, poppy; *3*, pine; *4*, maize, or Indian corn. In some kinds of seeds the cotyledons are very thin. In such cases we usually find that there is a great deal of food material *surrounding the embryo*, whereas in seeds with fleshy cotyledons there is food packed *within the cotyledon*. The food packed around the seed is called *endosperm*, which means "within the seed." (All shown in longitudinal section)

61. Seedlings. Examine a few seeds that have been planted two or three days, and you will see that the hypocotyl has emerged and is assuming the appearance of a root. At the other end of the embryo you may see the unfolding epicotyl. If we examine different stages of peas, squash, oats, corn, beans, and so on, we shall be able to see a great variety of methods by which the young plant crawls out of its covering and establishes itself in the soil (Fig. 35).

Large seeds, containing a large amount of reserve food, are apparently at an advantage, since they may develop more root and more shoot before they are overtaken by the necessity of providing themselves with food. We should therefore expect that plants with large seeds would be, on the whole, more

successful in establishing themselves in a new territory than plants with small seeds. We shall find, however, that the best spreaders in the plant world are those with rather small seeds.

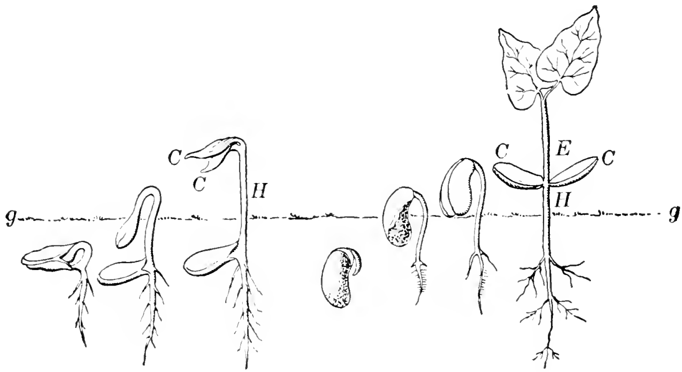


Fig. 35. Young plants emerging from seeds

On the left, squash; on the right, bean. In the squash a little outgrowth on the hypocotyl keeps the seed coat in place while the cotyledons are carried aloft. *C, C*, cotyledons; *E*, epicotyl; *H*, hypocotyl; *gg*, ground line

The speedy and secure establishment of the individual plant is of great advantage, but it is even more important that seeds be well scattered, and in this respect the small-seed plants with very numerous seeds have a decided advantage.

LIVING CONDITIONS; THE SEED

1. Nothing exists by itself
    - Living things are dependent
        - Upon non-living materials and conditions
        - Upon one another
2. Seeds as showing dependence
    - Dependence upon water
        - How demonstrated
        - Amount of water needed
    - Dependence upon temperature
        - Maximum; minimum; optimum
    - Relation to air

3. Seed structure
    Covers — Micropyle; (hilum) (Endosperm)
    Embryo
        Hypocotyl — Root; stem
        Cotyledon — One; two; many
        Epicotyl — Stem; leaves
4. Seedlings
    Structure
    Food supply
    Methods of emerging from ground

QUESTIONS

1. What objects move or act without relation to any other objects?

2. How can we tell whether soil is essential to the sprouting of seeds?

3. How can we find the conditions necessary to make seeds sprout?

4. How do sprouting seeds show that "enough is better than more"?

5. How does a grain (for example, the corn) differ from such a seed as the bean or squash seed? In what ways are they alike?

6. What structures in the seed are homologous to other structures that you have studied?

7. What part of a bean plant is homologous to the shell of a peanut?

8. What adaptations can you find in the structure and properties of the seeds that you have studied?

9. How could you show that the micropyle is not essential to the life of the ripe seed?

10. What practical use can be made of reliable knowledge regarding the conditions favorable to the sprouting of seeds?

11. What practical use can be made of the fact that certain plants accumulate considerable quantities of food material in the cotyledons or endosperm of their seeds?

12. Which conditions favorable to the sprouting of seeds are also favorable to the life of human beings? Which ones are not favorable?

REFERENCE READINGS

Bergen and Caldwell. Practical Botany, pp. 136–144.
Osterhout, W. J. V. Experiments with Plants, chap. i, The Awakening of the Seed; chap. ii, Getting Established.
Farmers' Bulletin 1175. Better Seed Corn.
United States Department of Agriculture. Yearbook for 1915. Reprint 679, How Seed-Testing helps the Farmer.

CHAPTER VII

THE SORTING OF PLANTS AND ANIMALS

Questions. 1. What is the use of classifying plants and animals? **2.** Why is it not sufficient to classify plants by size — herbs, shrubs, and trees? **3.** Why is it necessary to have so many main divisions? **4.** Why do we use Latin names for plants and animals? **5.** Why are not single names sufficient? **6.** What is the easiest way of finding out the name of a new plant or animal? **7.** Who makes up the scientific names of plants and animals? **8.** Is it necessary for everybody to know the scientific names? **9.** Is it necessary for anybody to know the scientific names?

62. Scientific classification. Many people derive satisfaction from collecting and sorting various classes of objects. Classification is of value because it helps in the work of reference. Just as classification of books in the library makes it possible to find a particular book, or a particular kind of book, with the least effort, so classifying plants and animals furnishes a convenient scheme for placing each specimen where it belongs.

If we sorted our books according to size, or according to color of binding, we should often bring two books on radio together; but we should be just as likely to bring together a book on radio and one on cooking, and we should be sure to separate books that really belong together. Every scheme for sorting plants and animals must provide a way of *bringing together* plants or animals that are truly related, and it must at the same time *keep separated* plants and animals that are not related, even though they have superficial resemblances.

The structure of organisms furnishes the basis for modern classifications, but the term *structure* has a wide significance. According to outward appearance we might place certain small snakes with certain large worms, but a study of the *internal* structure at once separates them very widely. Again, the ap-

pearance of certain caterpillars is much like that of certain worms; indeed, many people call caterpillars worms; but a study of the structure at various stages in the course of the organism's life—that is, its development—at once separates the two groups. We find that the caterpillar is the young stage of some insect (see page 30), whereas the worm never gets to be anything but an older worm. Modern classification of organisms accordingly considers *all* that can be known about living things, and not merely their appearance or their uses.

In recent times the study of classification has acquired new value because of the light it throws on problems of *new species*, and because of its aid in the study of heredity and plant and animal breeding (see Chapters XLV, XLVI).

63. The basis of classification. We have divided all organisms roughly into **plants** and **animals**, without trying to define either of these terms. We really ought to know more about them before we attempt any definition. Within each of these two principal divisions it is possible to say in a general way that a given species is "higher" or "lower" than another. Yet it is impossible to place all the known plants (or all the known animals) in a series from the lowest to the highest. This would be about as sensible, or as absurd, as trying to arrange all the people in a series from the worst to the best. We find that there are several main branches (among plants as well as among animals), some of which we should place higher and some lower. But we find in each branch so many degrees of complexity that there is considerable overlapping when it comes to arranging all the organisms. The diagram on page 74 (Fig. 36) will give a general idea of the relationships of the main branches of plants, and the one on page 75 (Fig. 37) will suggest the same for the animals.

In placing here the general scheme of plant classification and that of animal classification it is not intended that you should learn or memorize them by study. There are many terms in the descriptions of the various divisions and subdivisions which can have no meaning for the

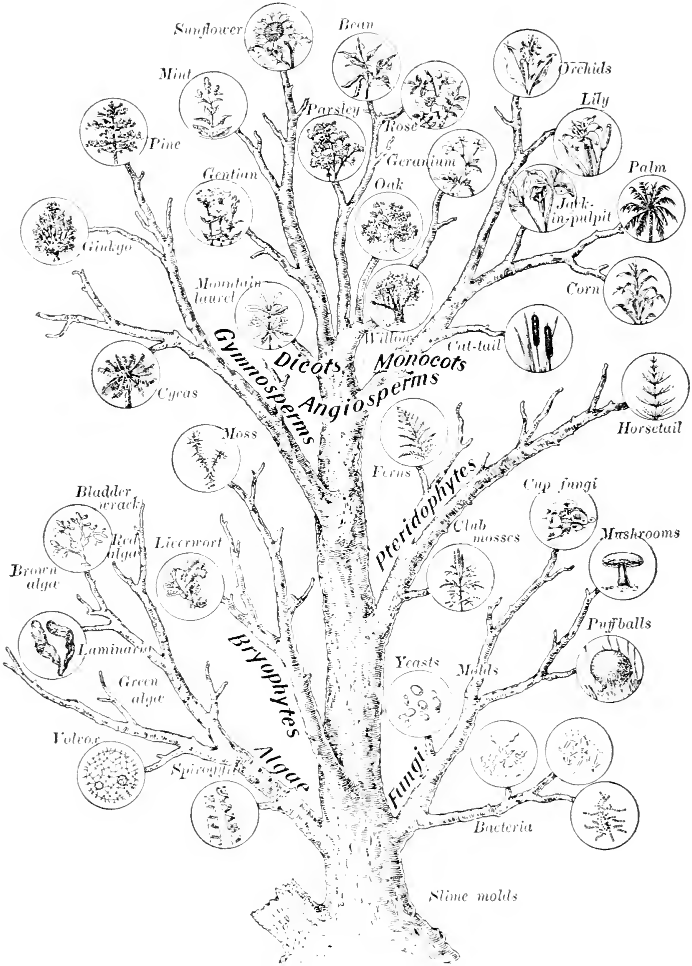


Fig. 36. Genealogical tree of plant life

This diagram is intended to suggest the common origin of all plant forms, with the constant progressive departure from ancestral types, now in one direction and now in another, like the branching of a tree. *Lower* and *higher* mean nearer to or farther from the original types. The closer together two forms are on a given branch, the more closely related they are considered (cf. Fig. 37)

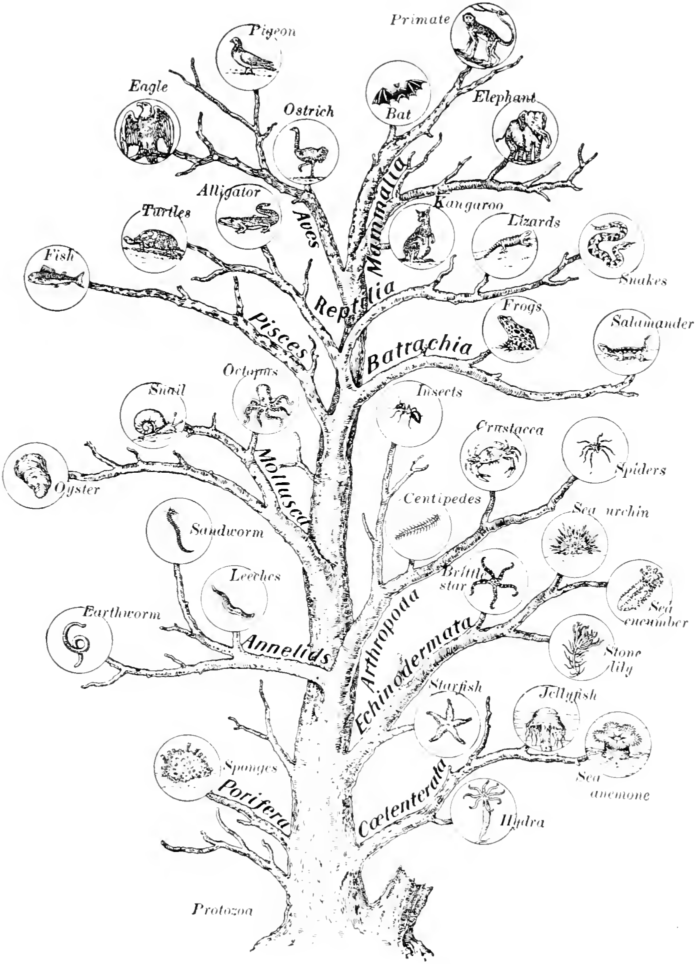


Fig. 37. Genealogical tree of animal life

This diagram is intended to suggest the common origin of all animal forms, with the constant progressive departure from ancestral types, now in one direction and now in another, like the branching of a tree. Of course only the main branches are shown. There are probably over a million species of animals living today (cf. Fig. 36)

beginning student; but from the examples given in each section you should be able to get a rough notion of where any specimen belongs. The best way to use these tables is to refer to them whenever a new plant or animal comes to your notice, in order to get an idea of the general position of the new species in the whole scheme. By using the diagrams and the tables in this way you will soon become familiar with the main branches and the more important classes. As you become acquainted with more plants and animals you will probably want to use a more complete classification.

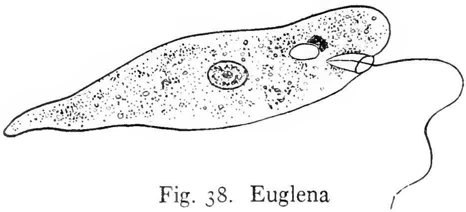


Fig. 38. Euglena

This one-celled alga is capable of moving about by means of the swimming lash, like many animals; it has chlorophyl, like many plants. Near the base of the lash is a reddish speck which is sensitive to light. Although it is often called an eyespot, it is no more like an eye than a grain of powder is like a cannon

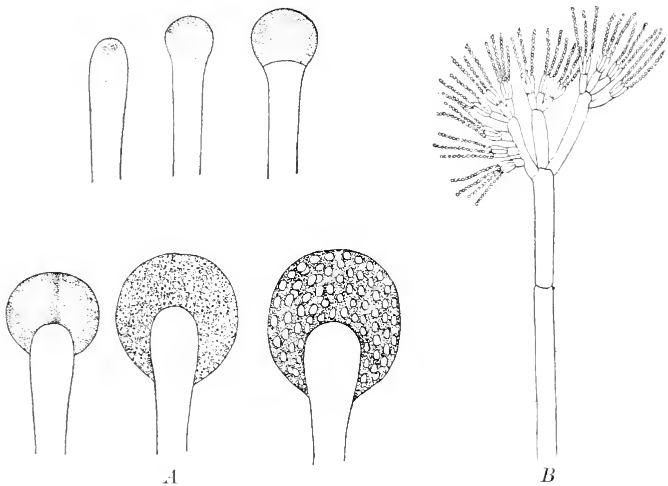


Fig. 39. Mold fungi

A: In the black molds, reproductive cells (spores) are formed by the repeated division of the protoplasm in an enlarging cell at the end of a thread. When mature, the inclosing wall breaks and the spores are scattered. *B*: In the blue molds, spores are formed by the successive separation of terminal portions of the branched threads. This is a type of fungus used in ripening Camembert cheese

64. The main groups of plants. The chief groups of plants are indicated in the following outline:

BRANCH I—THALLOPHYTES. Plants showing no differentiation into true stem and leaf.

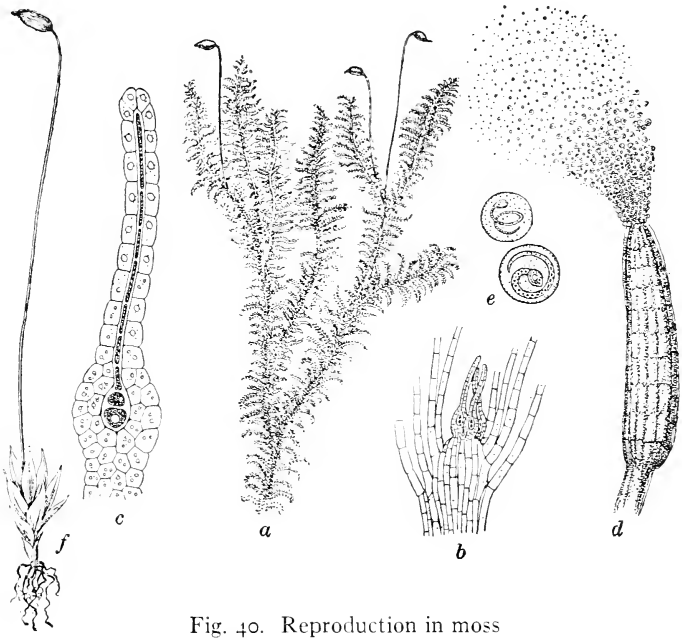


Fig. 40. Reproduction in moss

a, a leafy moss plant (*Hypnum molluscum*); *b*, section cut lengthwise through tip of one of the branches, showing position of *archegonia*, or egg-bearing organs; *c*, single *archegonium*, more highly magnified, showing single large egg cell; *d*, enlarged view of *antheridium*, or sperm-bearing organ, of *Polytrichum formosum*, discharging sperm cells; *e*, greatly magnified view of sperm cells; *f*, tip of leafy plant from the archegonium of which a spore plant has grown, showing stalk and spore capsule

A. SCHIZOPHYTES ("splitting plants"). Each cell splits into two; no other reproduction.

1. Cyanophyceæ. Splitting plants with chlorophyl—the blue-green algæ. (*Examples.* Oscillatoria, Rivularia, Nostoc.)
2. Schizomycetes. Splitting plants without chlorophyl. This group includes all the bacteria.

The distinction between having chlorophyl and not having chlorophyl separates all the thallophytes into two main groups, the algæ and the fungi.

B. ALGÆ. The chlorophyl-bearing thallophytes.

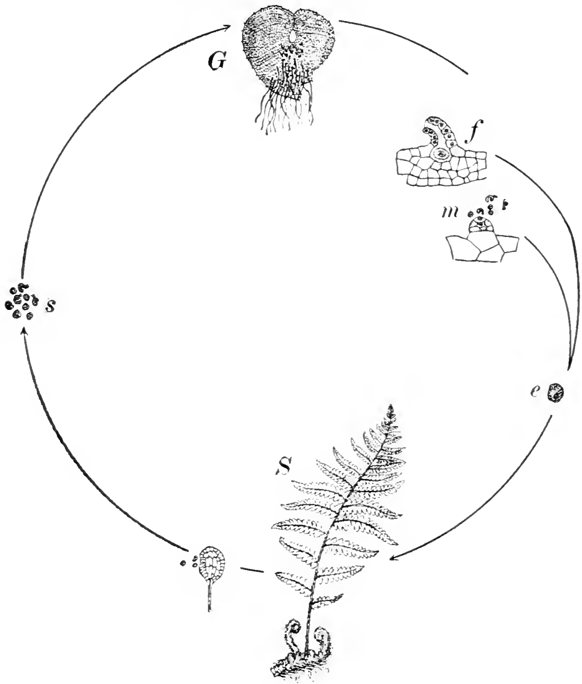


Fig. 41. Alternation of generations in the life history of the fern

G, the gametophyte, or gamete-bearing plant; *f*, the female gamete organ; *m*, the male gamete organ; *e*, the fertilized egg. *S*, the sporophyte, or spore-bearing plant; *s*, the spores discharged by the spore-bearing organ. The spore develops into a gametophyte; the gametes (egg) always give rise to a sporophyte. The alternate generations reproduce in different ways — one by means of gametes, or sexually, the other by means of spores, or asexually

1. The green algæ. Usually yellowish green. (*Examples.* Pleurococcus, desmids, Spirogyra, Vaucheria, stonewort, sea lettuce.)
2. The brown algæ. Mostly marine. (*Examples.* Bladder wrack, Laminaria, Sargassum, diatoms, sea palm.)

3. The red algæ. Mostly marine; reddish to purple. (*Examples.* Nemalion, Polysiphonia, Batrachospermum.)

C. Fungi. Thallophytes without chlorophyl.

1. Phycomycetes. Algalike fungi. (*Examples.* Water molds (often parasitic on fishes), phytophthora (the cause of the potato rot), grape mildew and other parasitic forms, black mold.)
2. Ascomycetes. Fungi bearing spores in sacs. (*Examples.* Yeast, cup fungi, the edible morel, the mildews, black knot.)
3. Basidiomycetes. Fungi bearing spores on outside of structure called basidium. (*Examples.* Rusts, smuts, mushrooms, pore fungi, shelf fungus, puffballs.)

D. Lichens. These curious structures are compound growths of fungi and algæ. The hyphæ in these partnerships generally belong to ascomycetes; the algal partner is a green alga related to pleurococcus or one of the blue-green algæ. (*Examples.* Reindeer moss, Iceland moss, Spanish moss. The common names introduce the word *moss*, although these plants are in no way related to the mosses.)

BRANCH II—BRYOPHYTES. Mosses and their allies. Archegonia but no vascular system.

A. Liverworts.

B. Mosses.

BRANCH III—PTERIDOPHYTES. Ferns and their allies. Archegonia and vascular system; no seeds. (*Examples.* Club mosses, quill-worts, scouring rushes (or horsetails), adder's-tongue, maiden-hair.)

BRANCH IV—SPERMATOPHYTES. Seed-bearing plants.

A. Gymnosperms. Naked-seed plants. (*Examples.* Sago palm, ginkgo, yews, larches, pines, cypress, sequoia.)

B. Angiosperms. Inclosed-seed plants.

1. Monocotyledons. (*Examples.* Cat-tail, water plantain, grasses, grains and sedges, palms, Indian turnip, rushes, spiderwort, lilies, bananas, orchids.)
2. Dicotyledons.

a. Archichlamydeæ. Flowers having no corolla or one of distinct petals. (*Examples.* Catkin-bearing trees (willows, walnuts, oaks, beeches), smartweed, pink family, buttercup family, water lilies, rose family, bean family, parsley family.)

b. Sympetalæ. Flowers having corollas in which the petals are united. (*Examples.* Heath family, primrose family, gentian

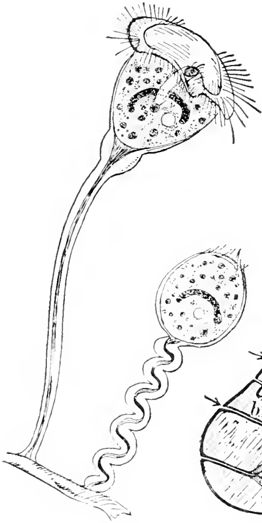


Fig. 42. Vorticella

This one-celled animal lives in water, attached by its stalk to a rock or twig. When disturbed it contracts the stalk and "bell" suddenly

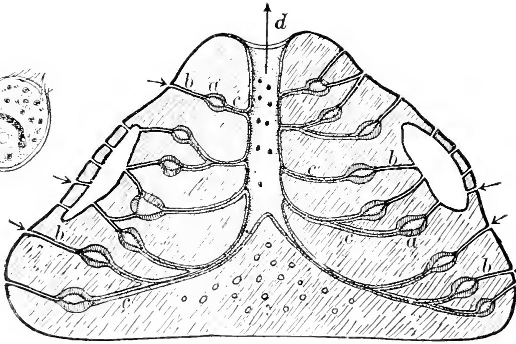
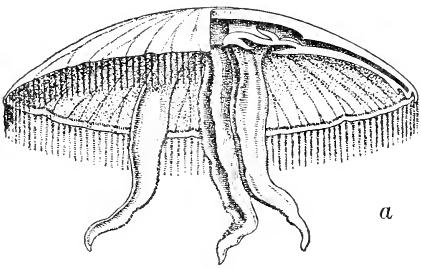


Fig. 43. Diagram of sponge structure

A sponge is a colony of cells arranged about hollow spaces, *a*, which are connected with the surrounding water by means of hollow channels, *b*, carrying currents inward, and by means of other channels, *c*, carrying currents outward through larger tubes, or "sewers," *d*. The currents are produced by the constant vibration of cilia projecting into the spaces, and they bring to the cells fresh supplies of food and oxygen, and carry away waste



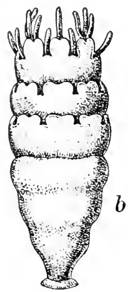


Fig. 44. The jellyfish *Aurelia*

The mature medusa, *a*, reproduces sexually, the gametes being thrown into the water, where fertilization takes place. The egg develops into an individual having the general form of a hydra, *b*, and attaches itself to a rock. The animal elongates and breaks up into a number of individuals by means of constrictions, so that it comes to resemble a pile of bowls. Each individual, when separated, turns over and swims away, changing into a medusa, *a*

family, mint family, morning-glory family, plantain family, madders, honeysuckles, composites—daisy, aster, sunflower, goldenrod, etc.)

65. The main groups of animals. The chief groups of animals are indicated in the following outline:

BRANCH I—PROTOZOA. The simplest animals; body of one cell. (*Examples.* Ameba, Paramecium, Vorticella, Plasmodium of malaria.)

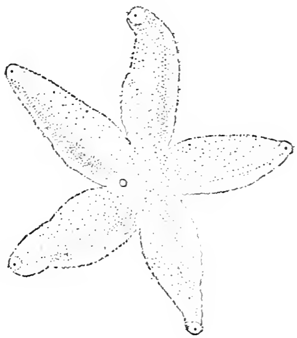


Fig. 45. Eyespots in starfish

The *eyespot* at the end of each ray is connected with the nervous system of the animal and is more sensitive to light than the rest of the body surface

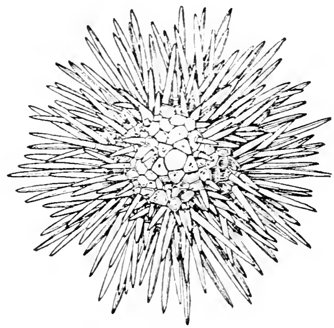


Fig. 46. Sea urchin

Animals of this branch deposit large quantities of lime in their skin, and produce knobs and spines that form a protective armor

BRANCH II—PORIFERA ("pore-bearing" animals). This includes all the sponges.

BRANCH III—CŒLENTERATA. Radially symmetrical animals having a single cavity in the body; all aquatic, mostly marine.

CLASS 1—HYDROZOA. (*Examples.* Fresh-water hydra, certain small jellyfish.)

CLASS 2—ACTINOZOA. (*Examples.* Most anemones, most corals.)

CLASS 3—SCYPHOZOA. (*Examples.* Most of larger jellyfish.)

BRANCH IV—FLATWORMS (Platyhelminthes). (*Examples.* Tapeworm, liver fluke, planarians.)

BRANCH V—ROUNDWORMS (Nemathelminthes). (*Examples.* Hookworm, trichina, thorn-headed worm.) Many of these animals are dangerous parasites on man or on domestic animals.

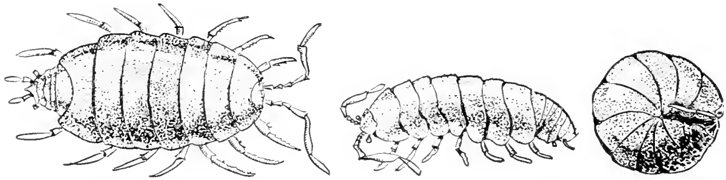


Fig. 47. The pill bug

When suddenly disturbed, this animal curls up, thus reducing its exposed surface and concealing its most delicate and sensitive parts

BRANCH VI—WHEELWORMS (Trochelminthes). The Rotifera, or wheel animalcules. Mostly microscopic.

BRANCH VII—ECHINODERMATA ("spiny-skinned" animals). Radially symmetrical, all marine.

CLASS 1—ASTEROIDEA. Starfish.
CLASS 2—OPHIUROIDEA. Brittle stars.
CLASS 3—ECHINOIDEA. Sea urchins.
CLASS 4—HOLOTHUROIDEA. Sea cucumbers.
CLASS 5—CRINOIDEA. Sea lilies.

BRANCH VIII—ANNELIDA ("ringed" animals). Wormlike animals with segmented bodies. The two most important classes are represented by earthworms, sandworms, etc. and by the leeches.

BRANCH IX—ARTHROPODA ("jointed-legged"). The body segmented; exoskeleton.

CLASS 1—MYRIAPODA ("thousand-legged"). (*Examples.* Myriapods, centipede.)

CLASS 2—CRUSTACEA ("crusty" shells). Head and thorax fused; water-breathers; antennæ. (*Examples.* Lobster, crayfish, crab, shrimp, barnacle, sow bug.)

CLASS 3—ARACHNIDA (spider family). Four pairs of legs; air-breathers; no antennæ. (*Examples.* Scorpions, spiders, daddy longlegs, tarantula, mites, ticks.)

CLASS 4—INSECTA. Segmented bodies; distinct head, thorax, and abdomen; antennæ, compound eyes; three pairs of legs; one or two pairs of wings (a few forms wingless); air-breathers. The chief orders of this important class are as follows:

1. Aptera ("without wings"). The most primitive insects now living. (*Examples.* Silverfish and springtail.)

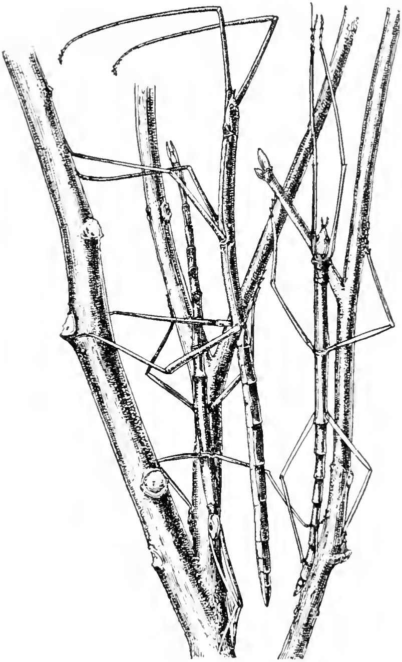


Fig. 48. The walking stick

This animal has startled many a person by walking away from a hand stretched out to grasp a leaf or twig. The insect is related to the locust and katydid, but it has no wings. Its body and legs are very long in proportion to thickness, and the enlargements at the joints and the irregularity of outline increase the resemblance to bare twigs. Moreover, the color of the animal changes with the seasons, from a bright green in the spring to a deep brown in the fall, thus matching its natural surroundings in a most remarkable way

Fig. 49. Praying mantis

This animal lies in wait for its prey with the front legs raised in a manner suggesting the attitude of prayer. It catches small insects with its strong front legs. Large species living in the tropics have been known to kill small birds

2. Orthoptera ("straight-winged"). Wings lying parallel with body or folding lengthwise; incomplete metamorphosis; biting mouth. (*Examples.* Locusts, crickets, walking sticks, katydids, cockroaches, mantis.)
3. Neuroptera ("netted-veined wings"). A large group broken up into several orders by entomologists; complete metamor-

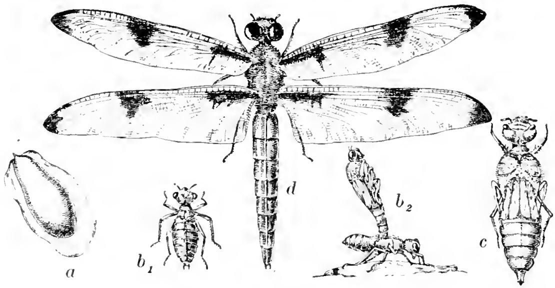


Fig. 50. The dragon fly *Libellula*

a, egg; b_1, young wingless larva; b_2, larva molting; *c*, nymph, or pre-adult stage; *d*, adult

phosis; biting mouth. (*Examples.* Mayflies, dragon flies, termites.)

4. Hemiptera ("half-wings"). Basal part of wings often thickened and without distinct veining; incomplete metamorphosis; sucking mouths. All true bugs. (*Examples.* Squash-bug, water-bug, plant lice, scales, lice, cicada.)
5. Coleoptera ("sheath-wings"). The front wing a hard protective cover; complete metamorphosis; mostly with biting mouth. (*Examples.* Beetles, weevils, fireflies, ladybird, June-bug.)
6. Lepidoptera ("scale-wings"). Rigid membranous wings covered with minute scales; complete metamorphosis; sucking proboscis. (*Examples.* All moths and butterflies.)
7. Diptera ("two-wings"). Hind wings reduced to tiny knobs, or balancers; complete metamorphosis; sucking or piercing mouth. (*Examples.* Mosquitoes, gnats, midges, house flies, stable flies, botflies, warbles, fruit flies.)
8. Siphonaptera ("tube-wingless"). Sucking mouth, wings reduced; complete metamorphosis; parasitic on birds and mammals. (*Examples.* Fleas of all kinds.)
9. Hymenoptera ("membrane wings"). Complete metamorphosis; biting or sucking mouth. (*Examples.* Wasps, hornets, bees, ichneumons, ants.)

BRANCH X—MOLLUSCA ("soft" animals). Unsegmented animals, most of them bearing shells.

CLASS I—GASTROPODS ("belly-footed"). Having shells of a single piece. (*Examples.* Snails, slugs, periwinkle, whelk.)

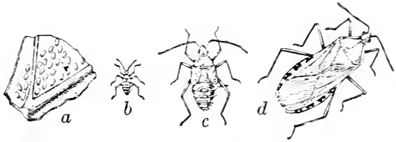


Fig. 51. Squash-bug (*Anasa tristis*)

a, eggs on leaf of plant; *b*, larva; *c*, pre-adult stage; *d*, adult

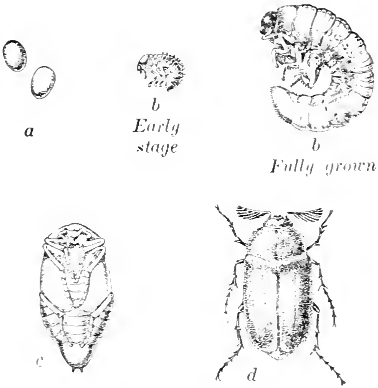


Fig. 52. The "June-bug" beetle (*Melalontha*)

a, eggs; *b*, larva, or grub; *c*, pupa, resting stage; *d*, adult

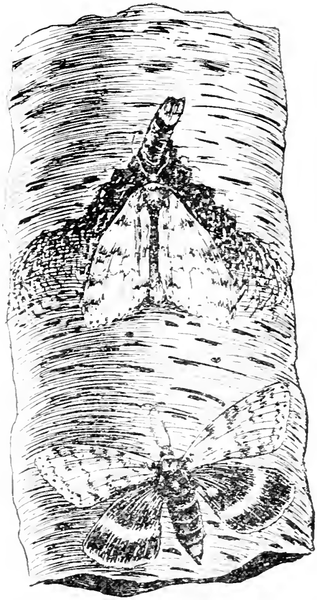


Fig. 53. The underwing moth (*Catocala*)

When they are at rest, the moths of this genus resemble the bark of trees, so that they are no doubt often overlooked by their enemies

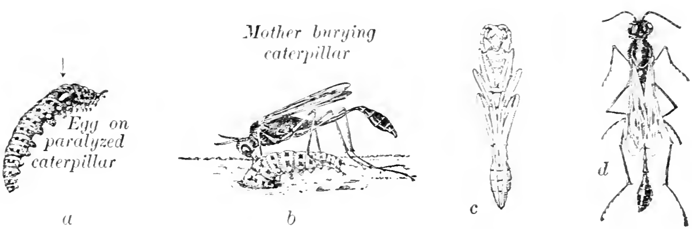


Fig. 54. A wasp (*Sphex gryphus*)

a, caterpillar in which the mother wasp has laid an egg; *b*, mother wasp burying the stung caterpillar in the ground. The larva feeds upon the caterpillar and changes into *c*, pupa, or resting stage, and *d*, adult

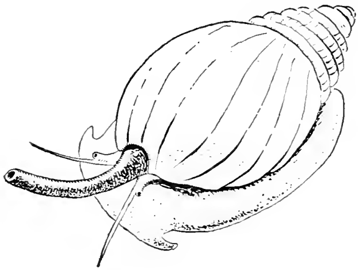


Fig. 55. The snail, a belly-footed mollusk

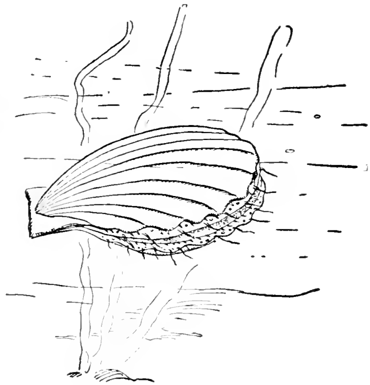


Fig. 56. The scallop

CLASS 2—PELECYPODA ("hatchet-footed"). Bivalve (having shells of two valves). (*Examples.* Oysters, clams, piddock, scallop, mussel, shipworm.)

CLASS 3—CEPHALOPODA ("head-footed"). The foot partly surrounds the head and has a number of arms, or tentacles. (*Examples.* Octopus, cuttlefish, squid, nautilus.)

BRANCH XI—CORDATA. Animals having a notochord, or internal axial basis for a skeleton. It is from this structure that the vertebral column develops. There are a number of small animals which never develop a true backbone, but which nevertheless have a structure that suggests the beginning of such a column. These are

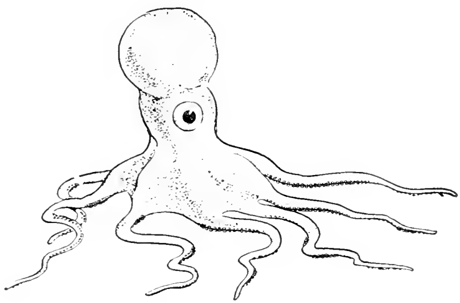


Fig. 57. The octopus, a cephalopod

These animals have eyes that resemble in many ways those of backboned animals

included among the cordata, although they are not strictly vertebrate. (*Examples.* Acorn worm, lancelet, sea squirt.) The five important classes of vertebrates are as follows:

CLASS 1—PISCES (fishes). The stone hag and the lamprey are sometimes called fishes, though they are distinct in having a round mouth (no jaws) and no fins or scales. They never develop bones, the skeleton remaining cartilaginous. There are four orders of true fishes:

1. Cartilaginous fishes. Gill slits not covered; "skin teeth." (*Examples.* Skates, torpedoes, sharks.)
2. Armored fishes (*Ganoidei*). Large, bony scales in the skin, especially about the head. In former times this order was very numerous. (*Examples.* Sturgeon and gar pike.)
3. Bony fishes (*Teleostei*). (*Examples.* Salmon, herring, perch, cod, flounder, etc.)
4. Mud fishes (*Dipnoi*). Fishes with lunglike structures. Only three living representatives, all in the southern hemisphere.

CLASS 2—BATRACHIANS (amphibia). Breathe by means of gills in early stages, familiar to us as tadpoles, and later develop lungs. Bony skeleton with two pairs of appendages; no exoskeleton. (*Examples.* Frog, toad, newt, salamander, mud puppy, hellbender.)

CLASS 3—REPTILIA. Wholly air-breathers; plates or scales in the skin. Four orders are usually recognized:

1. Chelonia. (*Examples.* Turtles and tortoises.)
2. Serpents. (*Examples.* Snakes, adders, cobras.)
3. Lacertilia. (*Examples.* Lizards, chameleons, horned toad, Gila monster.)
4. Crocodilia. (*Examples.* Alligators, crocodiles.)

CLASS 4—AVES (birds). Warm-blooded; exoskeleton of feathers; front limbs wings; tendency for the bones to fuse; air spaces in bones; no diaphragm; eggs with limy shells. Living species of birds may be divided conveniently into the *running* birds (ostriches, the cassowary, and the emu) and the *flying* birds. The latter include two groups of orders—the water birds and the land birds. Some of the important orders are as follows:

1. Anseres. (*Examples.* Swans, ducks, geese.)
2. Longipennes. (*Examples.* Gulls, petrels, terns.)
3. Pygopodes. (*Examples.* Loons, grebes, auks.)
4. Heron order. (*Examples.* Storks, ibis, bittern.)

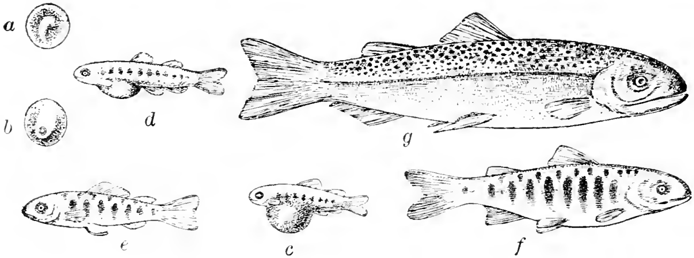


Fig. 58. Fish, Chinook salmon (*Oncorhynchus tschawytscha*)

a, egg; *b*, fish ready to break out of egg; *c*, more advanced stage; *d*, later stage, still showing yolk-sac; *e*, *f*, more advanced stages; *g*, adult stage

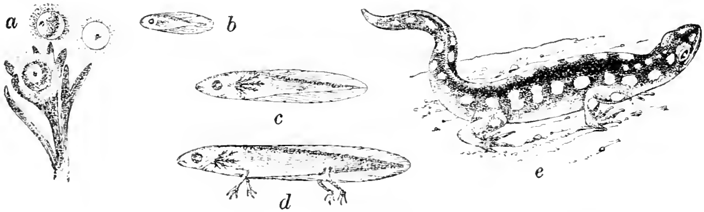


Fig. 59. Batrachian, newt (*Amblystoma punctatum*)

a, egg; *b*, first free-swimming stage, tadpole; *c*, more advanced stage, tadpole just before the appearance of hind legs; *d*, later stage; *e*, adult form

Fig. 60. Wallaby and young

The babies are not only protected and kept warm in the *marsupium*, or pouch, but are also nourished by a milky secretion produced by glands in the lining of the pouch

5. Plover order. (*Examples.* Snipe, curlew, rail, sandpiper.)
6. Gallinæ. (*Examples.* Hen, turkey, guinea fowl, peacock, pheasant, partridge, ptarmigan.)
7. Columbæ. (*Examples.* Pigeons, doves.)
8. Passeres. Perching birds; includes about one half of our native birds. (*Examples.* Sparrows and finches, swallows, robins, thrushes, crows, etc.)
9. Raptores. Predatory birds. (*Examples.* Eagle, hawk, owl.)
10. Pici. (*Examples.* Woodpeckers, sapsuckers.)
11. Cuckoo family (including kingfishers).
12. Whippoorwill order (including humming birds).

Class 5—Mammalia (mammals). Warm-blooded; hairy exoskeleton; diaphragm; suckle young.

1. Monotremata. Egg-laying mammals. (*Examples.* Duckbill, spiny anteater.) (With the exception of these two, all mammals develop the young within the body of the mother.)
2. Marsupials. Carry their immature young in a special abdominal pouch. (*Examples.* Kangaroos, wombats, opossums.)

The rest of the mammals are divided into the following orders:

3. Edentata ("toothless" mammals). (*Examples.* Sloths, armadillos, hairy anteaters.)
4. Cetaceans. (*Examples.* Whales, dolphins, porpoises.)
5. Sirenia. (*Examples.* Sea cow, manatee, dugong.)
6. Ungulata ("hoofed" animals).
   a. Odd-toe. (*Examples.* Horses, zebras, rhinoceros.)
   b. Even-toe. (*Examples.* Ox, sheep, antelope, camel, giraffe, deer, pig, hippopotamus.)
   c. Proboscidea (elephants).
7. Rodentia ("gnawers"). The largest order. (*Examples.* Rabbits and hares, squirrels, chipmunks, porcupine, gopher, muskrat, rats, mice.)
8. Insectivora ("insect-eaters"). (*Examples.* Moles, shrews, hedgehog.)
9. Chiroptera ("hand-wings"). (*Examples.* Bats, vampire.)
10. Carnivora ("flesh-eaters"). (*Examples.* Cat family, dog family, bears, weasel, seal, walrus, otter, mink, skunk, badger, raccoon, etc.)
11. Primates ("the first," or leading, order of animals, including man). This important order consists of the following families:

a. Lemuroidea. Small, squirrel-like animals living in trees and bushes. The lemurs are found in Madagascar, the marmosets in South America.

b. Cebidæ. The New World monkeys. Nearly all have long, grasping tails and flat noses. Smaller than the Old World monkeys. (*Examples.* Howling monkey, spider monkey, capuchin.)

c. Cercopithecidæ. The Old World monkeys. Tail not grasping, or short; nostrils pointing downward. Distinct, opposable thumb. (*Examples.* Baboons, mandrill, macacus.)

d. Simiidæ. The anthropoid (manlike) apes. No distinct tail; arms longer than legs. (*Examples.* Gibbons, orang-utans, chimpanzees, and gorillas.)

e. Hominidæ. The human race.

QUESTIONS

1. Why are there two names for each kind of plant and animal?

2. In what sense is the cat related to the tiger or lion?

3. What is meant by saying that one species is related to another?

4. What do we need to know about a plant or an animal before we can tell in what group to place it?

5. In what ways are the different plants in one branch alike?

6. In what ways are the different animals in one branch alike?

7. How can you tell to what class a particular animal belongs, even if you do not know what particular kind it is?

8. How is it that a plant or an animal belonging in one group can be mistaken for one in another group?

9. Why do people keep on changing the classifications of organisms?

REFERENCE READINGS

Bigelow, M. A. Applied Biology, chap. vii, Classification of Animals and Plants.

Moon, T. J. Biology for Beginners, chap. xxi, Arthropods.

Cockerell, T. D. A. Zoölogy, chap. xxii, Principles of Classification.

Calkins, G. Biology, pp. 162–172.

Any convenient manuals for the identification and classification of common plants, including trees, ferns, mosses, and fungi, and of common birds, insects, fishes, batrachians, mammals, etc.

CHAPTER VIII

MOTHER EARTH

Questions. 1. What do we mean when we say that "man is made of earth"? 2. In what sense is this statement not true? 3. What chemical elements are present in the human body but not in plants? 4. What chemical elements are present in the human body but not in the earth? 5. Are any elements present in the earth but not in the bodies of living things? 6. How can people find out what substances are present in a plant or animal?

66. Man is made of earth. What does this statement mean? Our flesh and blood and our delicate nerves are very different from the coarse materials of the earth, although the bones are more easily likened to stones. Some people seem to picture to themselves a clay image that is somehow suddenly inspired with life, like the miracle of Galatea. Yet the statement is perfectly true, and the process is as wonderful as any miracle, although we understand many parts of it pretty well. "Man is made of earth" because every particle in his body, like every particle in the body of every other living thing, comes directly or indirectly out of the soil, out of the water, out of the air—the material world in which we find ourselves. The food out of which we build up our bodies comes directly from the bodies of other animals or from the bodies of plants. These other animals nearly all derive their food from plants. The plants in turn build up their bodies directly from three sources—water, air, and soil.

67. The soil and the young plant. We saw that seeds can *sprout* without depending upon the soil. Yet we know that the soil is essential to the *growth* of plants, after the reserve in the endosperm or cotyledons is all used up.

We can plan experiments in which the various materials that make up soil (such as sand, clay, and the various salts) are used

separately and in combination. From such experiments we learn that it is not the sandiness of the soil, or the color, or merely the water in it that makes the growth of plants possible; it is *something in the soil that can dissolve in water.*

68. The salts of the soil. These soluble substances in the soil are the *salts*, of which there are many different kinds. Are all or any of these salts related to plant growth? In carefully planned and carefully conducted experiments plants were grown in solutions of soil minerals from which now one element and now another was omitted. The omission of some elements seems to result in no perceptible difference, but the omission of others will absolutely prevent the further growth of the plants. From the results of such experiments the following table has been constructed:

Element	Occurrence in Plants	Special Function
Aluminum	In lower parts	No function
Calcium	In leaves and stem	Related to the formation of plant cells; "makes plants hardy"
Chlorin	In lower parts	No function, so far as known, although present universally
Iron	In leaves and stem	Related to the formation of chlorophyl (see page 108)
Magnesium	In seeds and leaves	Related to the formation of seeds
Manganese	In lower parts	No function
Phosphorus	In seeds	Related to the activities of leaves; takes part in the formation of proteins (see page 109)
Potassium	In actively growing parts	Related to the formation of starch and sugar, and to the growing process
Silicon	In stems and leaves	No special function
Sodium	In stems and roots	No function, although present almost universally
Sulfur	In all growing parts	Necessary to the formation of proteins

This table shows whether or not a given element is found to be necessary for plant life. It also shows in what particular way each element is related to the life of the plant.

69. The composition of organisms. Another way of finding out what there is in the soil that the plant depends upon is to make an *analysis* of the plant to see of what it is composed. Analysis shows that certain elements are present in the plant body; some of these elements are also present in the soil. It is therefore reasonable to suppose that the plant derives these elements from the soil. It does not follow, however, that everything taken by the plant from the soil is of use to the plant. The most common elements found in plants are the following:

Carbon	Sulfur	Potassium
Oxygen	Phosphorus	Sodium
Hydrogen	Calcium	Iron
Nitrogen	Magnesium	Chlorin

Compare these with the composition of the human body (Fig. 3) to see how much we are like the plants. Chemical studies show that all animals have a composition differing very little from that of the human body.

The materials taken from the soil by the growing plant are sometimes called *plant food*. Strictly speaking, these are not food, as we shall see later (see Chapter X); they are merely some of the materials out of which plants manufacture their food.

70. Exhaustion of soil. After many crops of plants are removed the soil lacks some of the mineral salts required for plant growth. There is no danger of exhausting the iron in a soil, for this element is used in such small quantities that plants will have stopped growing for lack of some of the other elements (for example, phosphorus or nitrogen) long before the iron supply is considerably reduced. In some soils the same may be true of calcium. But the other elements are used in such large quantities (in proportion to the quantities present in most soils) that they practically limit the use of soil for crop raising. To make up for the withdrawal of materials by crops it has for ages been customary to put on or into the soil various substances called **fertilizers**. These include limestone or gypsum, barnyard manure, guano, crushed bones, ground phosphate

rock, and many others. In this country the farmers spend over $300,000,000 annually for commercial fertilizers, besides what they use from their own dungheaps.

The first use of fertilizers is to place in the soil the materials needed for plant growth. Certain fertilizers, however, are sometimes added not *to supply material* but *to produce chemical changes* in the soil, to make the latter more suitable for the growth of plants. For example, gypsum is commonly used to supply *calcium*; but in some cases it is used to make it easier for the plant to *get the phosphorus* in the soil.

71. Biology of the soil. The soil contains many different kinds of very small plants and animals, most of which can be seen only with a microscope. Some of these *microbes* are useful, as in the case of the bacteria living in the tubercles, or little swellings on the roots, of clover and alfalfa etc. (see page 301). Others, however, are injurious. Some of the latter may be destroyed by the addition of sulfur to the soil, with the result that the size of the crop is increased. Strictly speaking, the sulfur is not a fertilizer, although it helps to increase the yield.

Growing plants, like other living things, throw off waste matters. Some of these wastes thrown into the soil are poisonous. Certain materials added to soil containing such poisons are helpful, not because they add anything usable but because they *counteract the poisonous substances*. In a similar way certain materials may help by counteracting the poisons or acids produced by the usual inhabitants of the soil that we do not often see.

72. Intensive cultivation. By using fertilizers and other substances we may be able to keep the soil under cultivation indefinitely; yet as soon as all the suitable farm land is settled and cultivated there must be a crowding, or pressure, of population. Modern science teaches us how to get more food out of every acre of land through *intensive farming*. By forcing plants to grow more rapidly than they would ordinarily (by selecting early-maturing varieties, by covering against cold weather, by artificial watering, by more thorough tilling, and so on) the

cultivator is enabled to produce from two to seven crops a year on a given piece of land. This makes possible the support of a larger population on the same territory.

73. More soil. In this country nearly half the land area (outside of mountain and rock, which cannot be cultivated) consists either of swamp or of desert. Soil that is too wet is just as useless for farming as soil that is too dry. Through the coöperation of farmers and engineers and workers of all kinds it has been possible to reclaim millions of acres of desert lands, and to make it all usable for raising valuable crops. By draining the swamps and by bringing water to the arid regions, through miles of canals and ditches and pipes, soil containing vast quantities of food-making salts has been added to the national wealth. There is, of course, a limit to what man may be able to accomplish in the way of reclaiming land. In some of the Western dry regions the bringing of water may not be practicable if the distance is too great. At the present time more than half of the great staple food crops of the world are raised on artificially irrigated land (in China, India, Egypt, Canada, and other countries); the possibilities in this direction will probably not be exhausted for several generations.

74. Soil waste. The fertility of the Nile valley seems to be inexhaustible. This is not because the usable salts are more concentrated in this soil than they are in other soils. The richness of this soil is due to the fact that the river is constantly bringing down into the valley more and more material from the rocks in the mountains where the river has its sources. In our own country every river that empties into the sea carries away tons of usable minerals, which thus go to waste. In connection with some of the irrigation projects in the Southwest much water is lost during the spring, and with the water a great quantity of valuable mineral salts. Plans are being developed for saving this water in huge reservoirs, some of which are already completed. In this way it will be possible not only to irrigate larger areas but also to save from waste the soil materials out of which our food supply can eventually be increased.

75. The soil and population. The crowding of a population may mean not merely that people live too close together for comfort or for health; it may mean also a shortage of food supply due to insufficient soil for growing crops. As the population of a nation grows, the second kind of crowding is likely to become serious. There was a time when thoughtful people looked forward to such overcrowding with a feeling that it must result in great destruction of human life or in great suffering through general poverty. Indeed, in times past much of the poverty and famine, and even of warfare, was due to man's inability to get from the soil adequate supplies of food. At the present time, however, we are rapidly learning to increase the yield of our cultivated land out of proportion to the increase in population, chiefly through the application of biological knowledge.

So far as the soil is concerned, we need not fear that the "Great Mother" will become uninhabitable for many centuries. The pressure of the population, even if it becomes several times as great as it has been in China or India, can be met by the application of science and coöperative effort to the resources now in sight. If there is to be starvation, it will *not* be because the earth and the sun and the green plants fail us. It will be because of our own failure to make use of our knowledge in harmony and coöperation with our fellows.

MOTHER EARTH

1. Source of all living matter
   Earth; water; air
2. Elements taken from the soil by plants
3. Elements found in plants / Elements found in the human body

Elements found in plants		Elements found in the human body	
Carbon	Magnesium	Carbon	Magnesium
Oxygen	Potassium	Oxygen	Potassium
Hydrogen	Sodium	Hydrogen	Sodium
Nitrogen	Iron	Nitrogen	Iron
Sulfur	Chlorin	Sulfur	Chlorin
Phosphorus	Iodin	Phosphorus	Iodin
Calcium		Calcium	

4. Exhaustion of the soil
   - Elements that are not likely to be exhausted
   - Elements that are constantly removed in considerable quantities by crop plants: nitrogen; phosphorus; potash; calcium
   - Effect on farming
5. Use of fertilizers
   - Purposes
     - To replace needed materials
     - To destroy injurious organisms
     - To alter the chemical state of the soil
   - Kinds
   - Quantities and costs
6. Organisms in the soil
   - Injurious to plants
   - Helpful to plants
7. How soil is made to yield more
   - By selecting more prolific varieties
   - By selecting early-maturing varieties
   - By covering against cold weather
   - By artificial watering
   - By more thorough tilling
   - By systematic fertilizing of soil
8. How more soil is made available
   - By reclamation
     - Swamp (drainage): desert (irrigation)
   - Limits in reclamation
9. Waste of soil
   - Rivers emptying into the sea
     - Dissolved salt
     - Mechanically carried silt
   - (Relation to deforestation)
10. Relation of soil to population
    - The soil
      - Quantity
      - Quality
    - The people
      - How they use the soil
      - How they use their knowledge
      - How they deal with each other

QUESTIONS

1. What kinds of fertilizers are produced in your part of the country?

2. What kinds of fertilizers have to be imported into your region?

3. Why do farmers have to spend a larger part of their income for fertilizers in some regions than they do in others?

4. If there are abandoned farms in your part of the country, find out for what reasons any were abandoned besides the exhaustion of the soil.

5. If any abandoned farms have been reclaimed, find out what methods were used.

6. Have fashions changed as to the kinds or varieties of plants raised in your part of the country? In what ways are the newer plants more advantageous to the gardener or farmer?

7. What portion of the area of your state is naturally tillable? What percentage of the tillable land is being cultivated?

8. How much reclaimed swamp or desert land is cultivated in your part of the country?

9. Which of our regular commercial crops come largely from reclaimed lands?

10. What are the principal sources of soil loss in your part of the country? How can this waste be prevented?

11. How can a knowledge of plant chemistry help to reduce the cost of living?

12. How can the cost of living be reduced by preventing the growth of weeds in cultivated areas?

13. What is the advantage of increasing the human population of the country? of the entire earth? What is the disadvantage?

14. How can the earth be made to yield more on each acre cultivated?

REFERENCE READINGS

BERGEN and CALDWELL. Practical Botany, pp. 434–451.
BURKETT, C. W., and Others. Agriculture for Beginners, chap. i, The Soil.
WATERS, H. J. Essentials of the New Agriculture, chaps. xxiv–xxxi.
United States Department of Agriculture (office of the Secretary). *Circular 38*, Conservation of Soil (address by President Taft).
United States Department of Agriculture. Yearbook for 1917:
Reprint 728, Fertilizers from Industrial Wastes.
Reprint 729, Sources of our Nitrogen Fertilizers.
Reprint 730, Phosphate Rock, our Greatest Fertilizer Asset.
Reprint 733, Conservation of Fertilizer Materials from Minor Sources.
United States Department of Agriculture. Yearbook for 1920. Reprint 854, Uses of the Soil Survey.

PART II. THE BIOLOGY OF HEALTH

Without trying to define health at the start, we can take it for granted that it involves (1) keeping the body in condition; (2) making suitable use of the body; and (3) keeping our surroundings in condition

WHAT EVERYBODY WANTS

Human welfare depends upon the satisfactory use of our time in play and work. We find that very often people fail to attain satisfactory living because health is defective, and many people spend much of their thought and effort in chasing after health, as though that were the most important thing in the world. Very often, too, satisfactory living is impossible because people lack material things, or wealth. Accordingly, many men and women spend their thought and effort in the pursuit of wealth (which is represented to them by money), as though that were the most important thing in the world.

In the end both the health-seekers and the wealth-seekers fail to find happiness, for that is a bird that cannot be caught or trapped. If everything goes right about the place, it flies in through the open window and makes itself at home; and it stays just as long as everything does go right—and we ignore it. When we turn our attention to it, away it flies!

Health is necessary; a certain amount of wealth is necessary; but neither can be obtained by itself. Neither is possible without some measure of the other, and neither is possible except as we manage our bodies, our resources, and our relations to other people in the right way, that is, except as we work and play properly.

But we cannot work or play properly if we suffer from ill health or from a lack of material things. It is necessary to organize our everyday activities so as to take care of the essentials without being obliged to give too much thought to our health. But to do that requires a great deal of skill and understanding. A part of the understanding at least we can get from biology.

KEEPING THE BODY IN CONDITION

CHAPTER IX

THE MEANING OF FOOD

Questions. 1. Why must we eat food? 2. Must all living things have food? 3. How do plants take in food? 4. Have all animals mouths? 5. Is the food of one organism suitable for other organisms?

76. The material needs of protoplasm. We know that we must have food to keep us alive, but the connection between feeding and keeping alive is not always clear. Many people think that feeding is the same as eating; yet the plants and many animals have no mouths, and they also must feed. Since *it is the protoplasm that is alive*, we should think of food in relation to the peculiarities and activities of protoplasm.

The fact of *growth* means the need for *a material income suitable for protoplasm building*. It is impossible for protoplasm (or any other substance) to be made out of nothing. The fact of *movement* calls for *materials that can yield energy*. The nearly fluid state of active protoplasm, and the chemical changes that are constantly going on within it, call for *a water income*. We find also that *various salts or mineral substances* are a necessary part of protoplasmic constitution, although we do not know exactly how each one acts in this complex mixture. Some of the salts seem *to start* chemical processes among other materials that make up the protoplasm. Other salts (or elements, perhaps) appear *to modify* certain chemical processes, just as the bromide used by the photographer slows up the development of his negative; these are called *regulators*. In addition, nearly all protoplasm must have air, or rather *oxygen*, which the protoplasm gets from the air.

77. Nutrients. It is convenient to distinguish those incomes of an organism that serve as *protoplasm-building material* and those that serve as *sources of energy*, or fuel, as foods proper or, better, **nutrients**. These materials occur naturally only in the bodies of living things, and so are organic (see section 12).

Protoplasm-builders all contain the element *nitrogen*; they are called **proteins**. The proteins are represented in our common food by *albumen*, or white of egg; *casein*, or the curd formed when milk sours; *gluten*, or the pasty substance in wheat flour or bread. Similar nitrogen-containing substances are found in the muscle (flesh) cells of many animals and are called *myosin*. Others, found in the seeds of plants belonging to the bean family (the *Leguminosae*), are called *legumin*.

The *non-nitrogenous* nutrients are of two main classes, **fats** and **carbohydrates**. We are familiar with such fats as butter, suet, lard, tallow, olive oil, peanut oil, and others. The carbohydrates include all the sugars and starches. These substances serve as fuel, combining with oxygen and so yielding energy.

Protoplasm may be said to consist fundamentally of *proteins* suspended in *water* containing various *salts* in solution and various *other organic substances* dissolved or floating in it. The proteins have in recent years been further broken up into simpler nitrogen-containing substances called **amino acids**, which combine in various ways to make up the proteins.

Since protoplasm consists fundamentally of proteins, we shall expect to find protein in almost every part of every animal or plant. That does not mean that all animal or plant materials are suitable for food. In some materials the proportion of protein is very low; other materials contain additional substances which render them unsuitable as food, or at least as human food. All seeds contain some proteins; some in rather large proportions (for example, beans, peas, lentils). In addition to this all seeds contain either fat (as the castor bean, peanut, cotton seed, flax seed) or some carbohydrate (as the bean, cereals, the date).

78. Vitamins. During the past dozen years or so experiments made upon mice, guinea pigs, pigeons, and human beings have shown that, in addition to the protoplasm-builders (proteins) and fuels (fats and carbohydrates), certain substances must be present in our food to insure growth. Very little is known of

the chemistry of these regulators, but they have been grouped together under the name **vitamins**. Three groups of vitamins have been recognized. One, soluble in fats and oils, is called fat-soluble A. The other two, which dissolve in water but not in fat, are called water-soluble B and water-soluble C. It is likely that as these substances come to be better known they will receive more distinctive names based upon their composition, their actions, or their sources. For the present, however, enough is known to guide us in the selection of food, especially for infants and children and for those whose growth is not proceeding satisfactorily. We know also that pellagra, beriberi, scurvy, and probably other diseases result from the use of food that lacks one or another of the vitamins. These have accordingly been called *deficiency diseases*.

Unlike proteins and the fuel nutrients, vitamins do not seem to be universally present in all protoplasm. Still it may turn out that it is only a matter of quantity. Vitamin A (fat soluble) is most abundant in butter, or milk fat, in the yolks of eggs, in cod-liver oil, and in certain vegetables (see table on page 105). Water-soluble B is supplied by milk, tomatoes, lemons, spinach, carrots, cabbage, onions, parsnips, potatoes, the common grains, beans, and nuts. Yeast that has not been dried seems to contain a large proportion of this vitamin. The C group occurs most abundantly in cabbage, lettuce, tomatoes, lemons and oranges, and in smaller quantities in spinach, fresh peas, onions, and grapefruit.

In comparing different foods with respect to vitamins two interesting facts stand out. (1) Excepting eggs and dairy products, foods of animal origin have small or negligible quantities of the vitamins. Cod-liver oil, which is rich in vitamin A, is not commonly considered a food. (2) The cereals, which are fairly rich in vitamin B, contain these substances chiefly *in the outer tissues*, so that highly milled flour and polished rice are almost wholly without these essential materials.

79. Summary. From what has been said it should be clear that the material intake of the organism bears an important

relation to the protoplasm. We must therefore guard against thinking of food as related especially to the tissues or organs. There is no such thing as brain food or muscle food; all food is protoplasm food or it is not food at all.

We may summarize the material requirements of a living body in this way:

1. *Water.* The chemical changes that go on in living protoplasm can take place only in the presence of water. In the larger organisms water is also the chief medium for the transportation of materials within the body.

2. *Oxygen.* Although this is not usually regarded as part of the *food*, it is an essential part of the income of every cell. It is the chemical union of oxygen with other substances (organic) that sets free the energy by which the protoplasm does all its work.

3. *Protein.* Building material for the construction of new protoplasm or for the replacement of protoplasm that has been destroyed (oxidized) in the course of the activities of the protoplasm is supplied only by the amino acids of proteins.

4. *Fuel foods.* In addition to the proteins that are oxidized there is usually some other organic material that is oxidized. Two classes of compounds commonly furnish this fuel: namely, (*a*) *carbohydrates* and (*b*) *fats.*

5. *Salts.* Various mineral or inorganic compounds serve in the protoplasm as activators or regulators.

6. *Vitamins.* In some of the higher animals an essential part of the income consists of organic substances that influence growth and nutrition. Three groups have been recognized, which are called for the present A (fat soluble), B (water soluble), and C (water soluble).

THE MEANING OF FOOD

A. Organic substances
  1. Building material for protoplasm (for growth)
    Proteins (consisting of amino acids)
  2. Energy or fuel material (for movement and other processes)
    Carbohydrates — Fats
      Starches; sugars

RELATIVE AMOUNTS OF VITAMINS IN DIFFERENT FOODSTUFFS

The number of + signs after each item indicates the relative amount of the given kind of vitamin found in it. This information has been brought together by various workers from many sources

Classes of Foodstuffs	Vitamin A	Vitamin B	Vitamin C
Lean meats	+	+	+
Calf's brains	+ +	+ + +	?
Liver	+ +	+ +	+
Kidney	+ +	+ +	
Pancreas ("belly sweetbreads") . . .	O	+ + +	O
Thymus ("chest sweetbreads") . . .	O	O	O
Milk, whole	+ + +	+ + +	+ +
Milk, skimmed	O	+	+
Butter	+ + + +	O	O
Cream	+ + +	+	?
Cheese, full cream	+		
Eggs	+ + + +	+ +	O
Bread, whole wheat	+	+ + +	?
Bread, white		+ ?	
Rice, whole grain	+	+ + +	O
Rice, polished	O	O	O
Oats, maize (whole grain)	+	+ + +	O
Cereals, fine meal, bran removed . . .	O	O	O
Cabbage, fresh	+ + +	+ + +	+ + + +
Cabbage, dried	+ + +	+ + +	+
Spinach	+ + +	+ + +	+ + +
Lettuce	+ +	+ +	+ + + +
Sweet potatoes	+ + +	+ +	?
Parsnips	+ +	+ + +	?
Carrots	+ + +	+ + +	+ +
Potatoes	O	+ + +	+ +
Beans, peas, lentils, dried	O	+ +	O
Peas, fresh	+	+ +	+ + +
Onions	?	+ + +	+ + +
Apples, pears, limes	O	+ +	+ +
Lemons, oranges	O	+ + +	+ + + +
Grapefruit	O	+ + +	+ + +
Tomatoes	+ +	+ + +	+ + + +
Cod-liver oil	+ + + +	O	O
Lard, cottonseed oil, olive oil	O	O	O
Sugar, meat extracts, malt extract . .	O	O	O
Yeast, fresh	O	+ + + +	O

3. Regulators (influencing growth and other processes)
   Vitamins
      Fat-soluble A; water-soluble B; water-soluble C

B. Inorganic needs of protoplasm

4. Water
   Solvent — Medium in which proteins etc.
   Transportation agency — are suspended
5. Oxygen
   Combining with organic matter and so yielding energy
6. Salts
   Activators — Building material in part
   Regulators — (lime in bones)

QUESTIONS

1. What distinction should you make between feeding and eating?

2. What income of the body does not come through the mouth?

3. What kinds of nutrients would be used in relatively large quantities by a person who is growing rapidly?

4. What kinds of nutrients would be used in relatively large quantities by a person who is very active?

5. Why do we drink more water in warm weather than in cold?

6. What are some of the more important sources of proteins? of fats? of carbohydrates?

7. What are some of the more important sources of fat-soluble vitamin A? of water-soluble B? of water-soluble C?

8. What are some of the more important sources of salts in our diet?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, pp. 91–99.
Osterhout, W. J. V. Experiments with Plants, pp. 164–178.
Farmers' Bulletin 800, Foods the Body Needs.
Harrow, Benjamin. Vitamines, Essential Food Factors, chap. ix, Vitamines (extract in C. H. Ward's "Exploring Nature," pp. 186–189).
United States Department of Agriculture. *Bulletin 1138*, Vitamin B in Edible Tissues of Ox, Sheep, and Hog.
Public Health Reprint 689, Antineuritic Vitamin in Skim-Milk Powder.

CHAPTER X

WHERE FOOD COMES FROM

Questions. **1.** How do new supplies of organic material originate? **2.** Could all living things make their own food if there were no others from whom they could take it? **3.** How is air necessary for food-making? **4.** Is it true that plants breathe in what animals breathe out, and that animals breathe in what plants breathe out? **5.** Can plants live without roots? **6.** Where is the stem of the beet plant? **7.** What is the smallest piece of plant that can grow into a new plant?

80. Organic foods destroyed. When proteins, fats, and carbohydrates become *assimilated* into the protoplasm of any plant or animal, they are still available as food for other living beings; but when any of this material becomes *oxidized*, it is thrown out of the world of living things. Now, living matter can continue to live only at the expense of other living matter, and living matter is constantly being destroyed (oxidized). How, then, can the total amount of protoplasm increase or even remain the same? The answer to the question was found in the discovery that *the green parts of plants are active in making new organic foods out of inorganic materials.*

81. A manufacturing process. The making of organic substances out of inorganic materials may be compared to a manufacturing process. In every such process there must be (1) raw material, (2) tools or machines for working on the material, and (3) energy for driving the tools or machines. There is also (4) a main product and sometimes left-over material called waste or, better, (5) the *by-product.*

82. Factors in food-making. 1. The raw materials used by the plant are found to be *water* and *carbon dioxid.*

2. The plant's machines or instruments are different from those with which we are familiar. Instead of having wheels or

levers or other moving parts these machines are *chemical engines,* each consisting of a lump of protein with some of the **chlorophyl** (*chloros*, "green"; *phyllum*, "leaf") that gives familiar plants their distinctive color. Chlorophyl is the tool, or transformer of energy, in the food-making process (see Fig. 61).

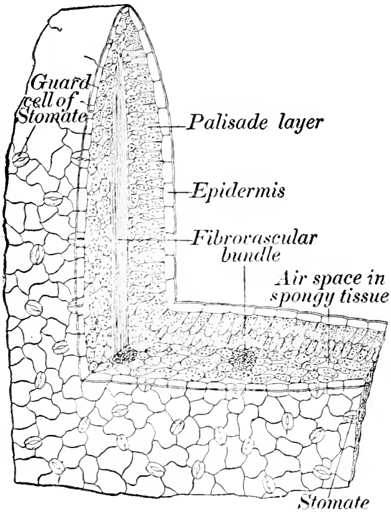


Fig. 61. Structure of leaf

The cells containing the chlorophyl (the *palisade cells* and the *spongy tissue*) get their income from the surrounding cells or from the surrounding air spaces. The *water* is brought up through the vessels of the wood (*fibrovascular bundle*) and it soaks through the cell walls. The *carbon dioxid* is absorbed from the air inside the leaf, and this air is in direct communication with the outer air by way of the breathing holes, or *stomates* (from the Greek *stoma*, "mouth")

3. The energy for doing this work is the light from the sun. Although the work cannot go on at too low a temperature, it is the *light* that is used in the process, and not the *heat*.

83. Oxygen a by-product. The starch or sugar formed by the action of sunlight upon chlorophyl contains the elements present in the raw materials, namely, carbon, hydrogen, and oxygen. In *starch*, hydrogen and oxygen occur in the same proportions as they do in water (H_2O). The raw materials taken in by the plant *contain an excess of oxygen*, since the carbon dioxid (CO_2) also furnishes oxygen. This element is given off in a free, or uncombined, state during the process of starch-making.

84. Sunlight and life. Some green plants never form starch; but they produce some kind of carbohydrate (usually some kind of sugar) by the sunlight acting on chlorophyl. This process of carbohydrate formation is called **photosynthesis**, from Greek words meaning "light" (compare *photo*graph) and "put to-

gether." In addition to forming sugar some plants have a way of condensing the sugar, shortly after it is formed, into starch grains (Fig. 62).

85. Origin of fats. All organic materials appear to be derived from carbohydrates. *Fats* originate in the cells of animals as well as of plants, by a modification of starches or sugars. Pigs and poultry can be fattened on food that contains no real fat or oil. Fats contain a large proportion of carbon and a small proportion of oxygen, compared to carbohydrates.

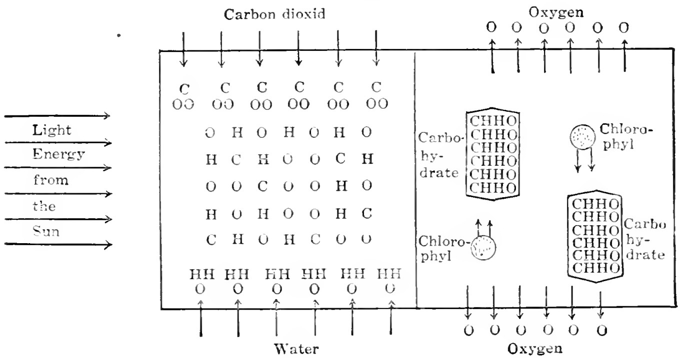


Fig. 62. Starch-making by chlorophyl

We may think of photosynthesis as taking place in two stages: in the first the raw materials, water and carbon dioxid, are broken up into their constituents—carbon, hydrogen, and oxygen; in the second these elements are recombined into carbohydrates, and the surplus oxygen is set free. The energy for this chemical process is sunlight; the transformations are brought about through the action of chlorophyl

86. Origin of proteins. The proteins are very complex substances. All contain nitrogen in addition to carbon, hydrogen, and oxygen. Some also contain sulfur, and some phosphorus. From careful studies of plants it appears that proteins are manufactured by certain cells when these are supplied with *carbohydrates* plus *salts* containing the necessary elements; for example, nitrates contain nitrogen, phosphates contain phosphorus, sulfates contain sulfur, and so on. A green plant is therefore capable of manufacturing its own food if it receives, in addition to the water and carbon dioxid, a suitable supply of minerals from the soil. Many plants without chlorophyl, as certain kinds of molds and yeast, are capable of manufacturing proteins when supplied with carbohydrates and suitable minerals. More recently we have learned that certain bac-

teria, molds, and yeasts and probably wheat and other green plants are capable of making proteins by using nitrogen from the atmosphere; this may prove to be a matter of great practical importance.

87. The leaf. The common green plants carry on photosynthesis in special organs, the *leaves*. The most common fact about a leaf is that it is flat and comparatively thin.[1] Some leaves have stalks, or *pedicels*, and all have *veins* running through the flat portion, or *blade*. They differ as to the character of the edge. Some are smooth, whereas others have wrinkled, uneven surfaces. Some kinds are hairy, while others are quite bald. Even the color of leaves is not uniform, for the chlorophyl varies in density, and in some plants the appearance is modified by other coloring matters, the hair, etc. (Fig. 63).

88. Work of the leaf. The structure of a leaf is shown in Fig. 61. The oxygen given off by the cells passes into the air spaces and diffuses from these to the exterior by way of the **stomates** (see Fig. 64). The skin cells are not directly concerned in the work of starch-making. Their function may be described as protective. They protect the delicate pulp cells against mechanical injuries and the whole plant against the loss of water.

89. Transpiration. The loss of water is perhaps the most serious danger to which most plants are exposed, since more plants die from the results of wilting than from any other one cause. And yet **transpiration**, as this evaporation from the leaves is called, may be of use to plants indirectly.

The rapid evaporation of water results in *lowering the temperature of the plant*. If conditions interfere with transpiration, the temperature of leaves exposed to sunshine increases so rapidly that the protoplasm is sometimes killed. This kind of occurrence may be observed in the summer time, when the sun comes out quickly after a shower that has left a great deal of moisture in the air. The moisture in the air prevents transpiration; the sunshine is largely converted into heat inside the leaves, and as a consequence the protoplasm is injured.

[1] In some plants leaves depart considerably from this model. Some leaves are nothing more than fine hairs, as on certain cactuses; others have extensions that behave like tendrils; and some are spines. Certain plants have leaves that are more or less active in capturing animal food.

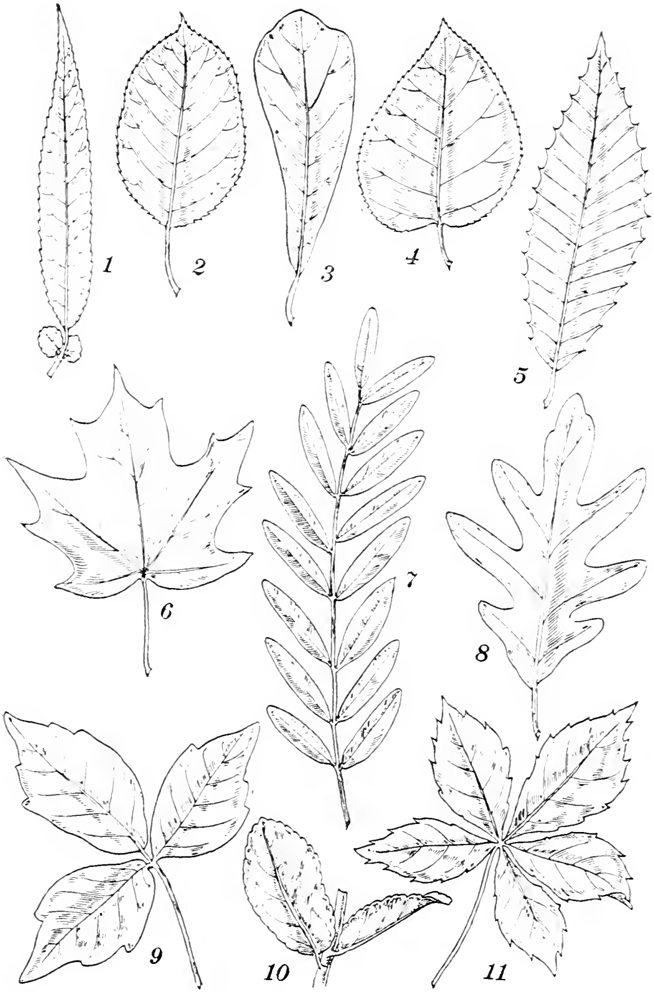


Fig. 63. Various forms of leaves

1, black willow, showing *stipules* at base; *2*, apple; *3*, water oak; *4*, hobble bush; *5*, chestnut; *6*, sugar maple; *7*, compound leaf of honey locust; *8*, white oak; *9*, compound leaf of poison ivy; *10*, live-forever; *11*, compound leaf of Virginia creeper

90. Light and leaves. In the absence of light, chlorophyl is inactive and the process of starch-making is suspended. Moreover, if a plant is kept in darkness for a longer period, the chlorophyl begins to disappear, and in the end the leaf will be quite white. This fact is used in the blanching of celery. When we compare the outer leaves of a head of lettuce or cabbage with the inner leaves, we see a difference in the amount of green pigment, which illustrates the same principle.

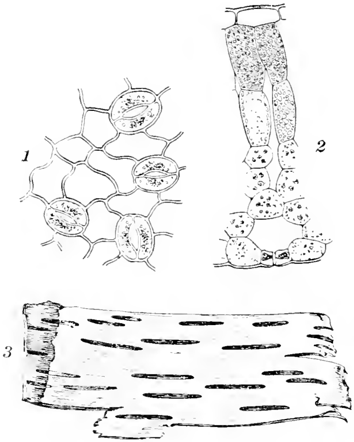


Fig. 64. Breathing holes of plants

1, stomates, or breathing pores, on the surface of a leaf, inclosed by the "guard cells." *2*, section through a leaf, showing an air space just inside the guard cells. Stomates are found in the epidermis of twigs as well as on leaves. As the stem grows tougher the breathing holes become larger and more irregular patches connecting the spaces between the cells and the outside atmosphere. The roughened breathing spaces on the bark are *lenticels*. *3*, lenticels on the bark of birch. (Microscopic views about × 200)

Experiments on light in relation to photosynthesis show that it is quite possible for plants to carry on this work under artificial light. By the use of strong electric lights it has been possible to hasten the growth and development of lettuce so as to get it on the market at least two weeks earlier than could otherwise have been done. The plants were given daylight while there was any, and were then supplied with artificial light during the night. In this way plants can be kept working continuously, as they apparently have no need for rest or sleep. More recently a crop of wheat was harvested in Minnesota, having developed "from seed to seed" in continuous artificial light.

91. Uses of leaves. Leaves are the original sources of most of our food. The leaves of many plants are of use to us directly. Some are eaten, as, for example, cabbage, lettuce, spinach, water cress, dandelion. The leafstalks of rhubarb and celery are also used as food, although they do not contain very much

protein, fat, or carbohydrate. Tea and tobacco are used because of the presence of an **alkaloid**[1] that makes the leaves of these plants interesting to human beings.

The fact that plants throw large quantities of oxygen into the air makes them valuable neighbors, especially in the cities, where oxygen is used up relatively faster on account of the crowded population and the many fires.

Our domestic animals feed largely on the leaves of plants: grass, beet tops, hay, alfalfa, clover, and corn fodder furnish the principal green food of cattle and horses.

The dead leaves of plants (whether they have dropped in the autumn or have reached the ground through the death of herbs etc.) form the basis of the **humus** of the soil. Humus is a mass of decaying vegetable matter, with some animal matter and soil. This forms a soil covering that is very helpful from the point of view of *retaining moisture in the soil*, and to a certain extent it also serves in returning nitrogen and other elements to the soil.

92. Simple food-makers. There was life upon the earth (and therefore some way of making food out of simpler substances) long before there were any leaf-bearing plants. In some of the simplest plants the whole body consists of but a single cell. Among the commoner examples are the green slime (see section 47 and Fig. 30) and the pond scum or "frog spit" (*Spirogyra*) that we find floating on the surface of ponds. In such plants each cell carries on all *the activities that together make up being alive*—all the activities that in larger and more complex plants are carried on by different special parts or organs. In the most complex plants some activities are carried on by every cell, but certain processes are specialized: there is division of labor among the root, the stem, and the leaf.

93. The root. This organ takes on many different forms, from the thin, stringy roots of grasses to the massive fleshy or woody roots of beets or trees (Fig. 65). But in a general way it may be considered an organ of *attachment* and of *absorption*.

[1] An alkaloid (that is, something that is "like an alkali") is an organic compound containing nitrogen and capable of combining with acids.

Differences in form are often related to the conditions under which the plants live. Thus, fleshy roots are often associated with the *biennial* (two-year) habit. In such plants as beets, carrots, and parsnips the plant's first season is spent in manufacturing food and depositing it in the root. The next year comparatively little foliage is produced, but a stalk bearing flowers uses up substantially all the food that had been accumulated. In contrast with this habit of life we find the plants that sprout,

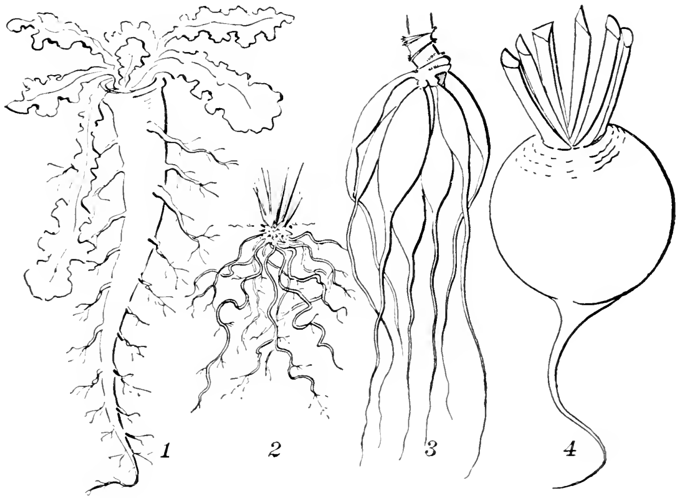


Fig. 65. Forms of roots

1, taproot of dandelion; *2*, fibrous root of buttercup; *3*, bundle (or fascicled) root of dahlia; *4*, fleshy root of beet

grow to maturity, and die, all within one season. These *annual* plants develop in their short lives rather delicate or fibrous roots, as a rule.

Trees and woody shrubs, which continue to live year after year, develop massive shoots. Corresponding to this fact we may note that such plants also develop elaborate, strong roots. From this we may see that the structure of the root and its functions are closely related to each other and to the character of the plant. There is a connection (1) between the structure of the root and the size of the plant that it anchors, (2) between the size of a root and the length of its life, and (3) between the size of a root and its food-accumulating or its absorbing activity.

In many plants the main root continues to grow downward into the soil as long as the plant lives and as long as the tip of the root remains

uninjured. Such a main descending root is called a taproot. The fleshy roots that have been mentioned are all taproots; and a number of trees, as certain kinds of maples, also produce taproots. When a taproot is injured or cut off, some of the side roots turn and grow downward. In a few cases the tip of the taproot, when not too much injured, can grow a new tip and continue the main line of growth.

The first function of a root may be said to be the absorption of water and of dissolved substances. This work is carried on by the "root hairs" (see Fig. 66).

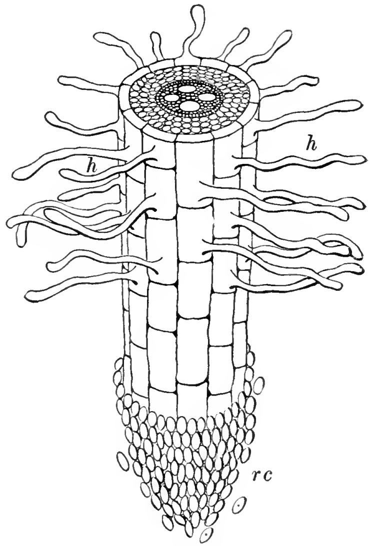


Fig. 66. The tip of a young root

The root hair is a single cell formed by the outward prolongation of one of the skin cells. The root hairs are the actual absorbing organs. Each root hair lives but a short time and then shrivels up. As the tip of the root grows on, new root hairs are formed. The older skin cells of the root die and their contents dry out. Together with the shriveled root hairs these skin cells form a protective covering through which water does not pass very readily. As the plant becomes older and uses up more water, the absorbing area of the root is increased by the formation of many side roots and by the branching of the roots. But it is always in the region near the growing tip of the main root and of the many branch rootlets that absorption takes place. The rootcap *rc* protects the growing point

94. Structure of roots. To understand the structure of roots, use a carrot or parsnip root that has been standing for twenty-four hours or longer with its tip in water containing red ink. Cut slices both crosswise and lengthwise, and use a magnifying glass (see Fig. 67).

The fiber and vessel cells can grow, but they cannot divide. In the young root there appear layers of cells which separate the water-carrying bundles from the food-carrying bundles. These **cambium** cells are capable of producing new fiber and duct cells of the two kinds—the water-carrying, or **wood**, and the food-

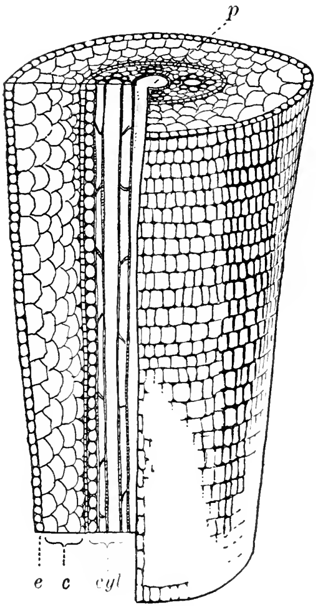


Fig. 67. Diagram of root structure

The skin, or outer layer, *e*, is called the epidermis. Under this comes the bark, *c*, or cortex. The central portion, running lengthwise of the root, *cyl*, is the central cylinder and corresponds to the wood of a stem. In either a cross section or a longitudinal section you can distinguish the central cylinder from the cortex. Some of the long cells in the central cylinder serve as tubes or vessels through which liquids move up into the stem. Other vessels in the central cylinder carry food materials from the leaves and stems down into the growing parts of the root. In addition to the cells which form ducts there are others with thickened walls. These fibers add to the toughness and rigidity of the cylinder. Bundles of fibers with water-conducting vessels or of fibers with food-conducting vessels are called *fibrovascular* bundles, *fibro* meaning "of fibers" and *vascular* meaning "of vessels" or tubes. *p*, the pith

carrying, or **bast**, system. Growth in length results from the formation of new cells by a special growing layer near the tip of the root.

95. Uses of roots. Many plants have the habit of depositing food in their roots: starch, sugar, and proteins. Although our fleshy vegetables contain from about 80 per cent to 90 per cent of water after the skin is removed, they are still worth using for their organic substances and the useful mineral salts. These vegetables have a relatively large bulk of cellulose, which is helpful in stirring the intestines to action (see page 154).

Fleshy roots are used in large quantities as fodder for cattle. Some roots serve also as sources of drugs and flavorings, as licorice root, sassafras root, and sarsaparilla.

Because root hairs adhere very closely to grains of sand in the soil, roots are very effective in binding the soil, enabling it to withstand the wearing away by water and by wind. For this reason certain kinds of grasses are sometimes planted on sandy strips

to prevent the complete removal of the sand by the winds. The hillocks formed by clumps of such plants may continue to enlarge for years, and to give protection to other kinds of plants until the earth has become compact (Fig. 68).

Roots do not generally put forth buds or shoots, but the roots of a few plants do so—certain willows, poplars, and hawthorns.

Fig. 68. Sand dunes at Pine, Indiana

The roots and underground stems of the grass *Calamovilfa longifolia* bind together the grains of sand, and larger and larger soil masses are gradually formed. Barren sand is blown about by the winds. (From photograph by Dr. George D. Fuller)

Roots of such plants can therefore be used for propagating the species. In some plants the roots will form new shoots if the old shoot is completely removed or destroyed. Roots frequently arise from stems or leaves, thus making possible the propagation of plants by means of cuttings (see Fig. 69). Blackberry and raspberry bushes are frequently propagated by *layering*, which consists of bending the flexible stems outward and burying the tips in the ground. New roots are formed on the covered portions, and, later, buds form new shoots. The old connecting

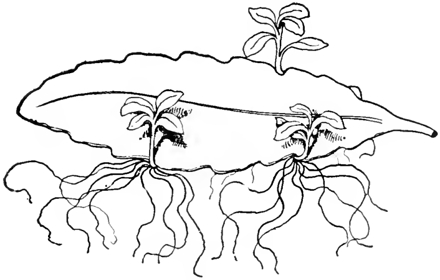


Fig. 69. Adventitious roots

If the leaf (or even a piece of leaf) of a bryophyllum be placed on damp earth or sand, tiny roots will form at certain points along the edge. Buds will also be produced, so that after a while we can separate small but complete plants and get these to grow into full-sized individuals. The same results can be obtained with the common house plant begonia

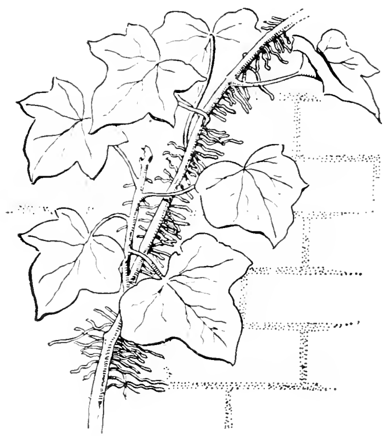


Fig. 70. Climbing roots

The English ivy, like many other climbing plants, clings to its support by means of adventitious roots that grow out all along the stem. The poison ivy also climbs by means of adventitious roots, and in some of the tropical tree-climbing plants the roots are fully developed as holdfast organs

stem is then cut away. A similar process takes place naturally in the strawberry plant: its creeping stems bear a cluster of new roots at each tuft of leaves, so that in the course of a season a single plant may spread out and cover a large area.

Roots that originate from stems or leaves are called adventitious roots (see Fig. 70). In the Indian corn and some other plants adventitious roots serve as props (see Fig. 71). The banyan tree of Asia puts forth supporting adventitious roots from the horizontal branches.

96. The stem. Connecting the leaf with the root is the stem, which is both an organ of *support* and an organ of *transportation.* The water and salts from the roots pass through one set of tubes, and the manufactured food from the leaves through another.

The fibrovascular bundles conducting water from the roots are called **xylem**, or wood. Those conducting saps from the leaves are called **phloëm**, or bast. The end walls of the bast vessels have pores in them and are called **sieve plates** (Fig. 72).

In woody plants the xylem bundles are arranged in concentric cylinders, or tubes inside of tubes, and make up the wood. The phloëm bundles are arranged around the wood, in the inner portion of the bark. Between the outer layer of wood and the inner layer of bast is the **cambium**, or growing layer, from which all the new xylem and all the new phloëm cells originate.

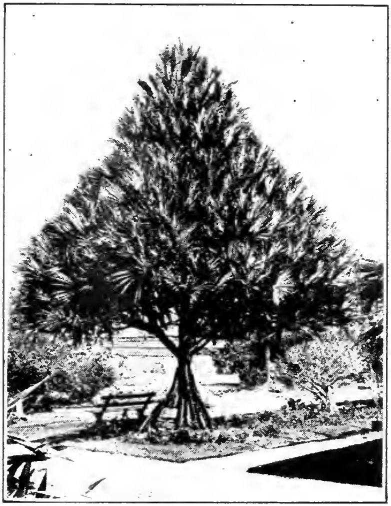


Fig. 71. Prop roots

Near the base of the trunk the screw pine (*Pandamus*) sends out prop roots in a manner similar to that of the Indian corn. (From photograph lent by the New York Botanical Garden)

The fibrovascular bundles branch and divide so that they reach into all the twigs and leaves. In the leaf they branch again and make up the so-called veins or nerves of the leaf blade. The sap-carrying vessels of the root are connected with similar tubes found in the stem. In many plants the bundles of vessels and fibers are readily pulled out from among the surrounding pith cells. In celery these bundles make up the "strings," and in the plantain the so-called "nerves" that we see sticking out of the stalk when we pull up a leaf.

97. The circulation of sap. We do not yet understand all about the rise of sap in trees. It is certain, however, that the water taken in by the roots does rise to the leaves, and that it goes through the xylem vessels. We know also that organic food is formed in the leaves, and that it accumulates in roots

and underground stems of many plants. There must, therefore, be a current of material passing downward.

A tree that is girdled (that is, one that has a ring of bark removed) will continue to live for the rest of the season. This shows that the removal of the bark does not interfere with the ascent of water and salts from the roots to the leaves. The following spring, however, when the opening of the buds with the rapid expansion of leaves and twigs depends upon food accumulated during the previous summer, the tree will be found dead. Although water and salts may still be able to reach the upper parts of the plant (since the channels that served during the previous season are still open), the food that should have been accumulated during the previous summer is now lacking.

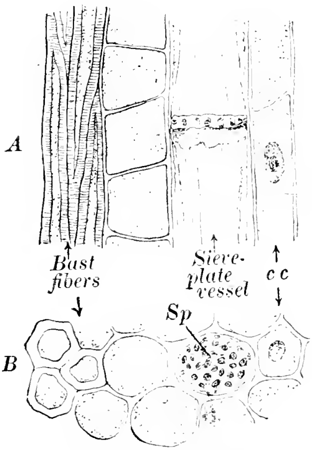


Fig. 72. Bast fibers and vessel

A, a section cut lengthwise, and *B*, one cut crosswise, showing bast fibers, sieve-plate vessel, *Sp*, and the so-called companion cells, *cc*, found next to the sieve-plate cells. (× 400)

By far the largest portion of the water that moves from the roots to the leaves evaporates and never comes back.

The smallest plants that we ordinarily notice thus show a great division of labor, with special organs and special tissues.

98. Our dependence upon chlorophyl. The parts of a plant that have no chlorophyl (for example, the root or the stem of a tree) are unable to make food substances out of inorganic materials and are nourished by materials obtained from the leaves; but animals and such plants as mushrooms, having no chlorophyl, must get their food from the bodies of other living things. In the end *all food comes from green plants.*

That is to say, through the action of light on chlorophyl, the carbon and the oxygen in CO_2 become separated so that they are capable of again combining and liberating, or setting free, energy. A carbohydrate may thus serve as a source of energy by becoming oxidized, either in the

bodies of living things or in a flame. Thus we may see that all the energy which plants and animals use as a result of the oxidation of carbohydrates is derived from the sun's energy. There is more than poetry in the statement that every human act is a transformed sunbeam.

WHERE FOOD COMES FROM

1. Organic matter is constantly being destroyed
   - Through oxidation in protoplasm
   - (Through decay)
   - (Through fire and industrial processes)
2. Organic matter is constantly being made anew
   - Primarily
     - Through photosynthesis
       - Material: water (H_2O); carbon dioxid (CO_2)
       - Instrument: chlorophyl
       - Energy: sunlight
       - Product: carbohydrates
       - By-product: oxygen
   - Secondarily
     - Through transformation of carbohydrates
       - By plant and animal protoplasm
       - Into fats; into proteins
     - Through assimilation of nutrients (proteins, fats, and carbohydrates)
       - By plant and animal protoplasm
       - Into substances peculiar to the different species of plants and animals
     - Through (other) chemical processes of protoplasm
       - Into substances peculiar to the activities of different species of plants and animals
3. Structure and activities of chief food-producers (seed plants)
   - The leaf
     - General character
     - Origin
       - From stem
         - Epicotyl
         - Cotyledon
       - (From buds)
     - Different forms (compare also parts of flower)
     - Structure
       - Epidermis
         - Stomates
         - (Hairs); (Wax)
       - Pulp (chlorophyl-bearing cells)
         - Palisade layers
         - Spongy (air-space) layers

- Veins (fibrovascular bundles)
  - Fibers (mechanical support)
  - Vessels (conduction)
    - Bringing water and salts to chlorophyl cells
    - Taking away finished food

The root
- General character
- Origin
  - Primary
    - From hypocotyl
  - Secondary
    - From other roots
    - From stem } adventitious
    - From leaf } adventitious
- Different forms
  - Taproots
  - Fibrous roots
  - Fascicled roots
  - Prop roots
  - Climbing roots
  - Aërial roots
- Structure
  - Epidermis
    - Root hairs
    - Rootcap
  - Cortex
  - Pith and central cylinder, including fibers
  - Vessels
    - Conveying water and salts toward stem and leaf (xylem)
    - Bringing finished food toward growing region (phloëm)
  - Growing regions
    - Cambium layer; growing point
- Functions
  - Anchorage (holdfasts)
  - Absorption of water and salts
  - (Propagation)
  - (Storage of reserve food)
  - (Climbing)

The stem
- General character
- Origin
  - Primary
    - From epicotyl
  - Secondary
    - From other stems
    - From root } adventitious
    - From leaf } adventitious
    - From injured stem } adventitious

Different forms
- Erect
  - Simple; branched (various types of branching)
- Shortened ("stemless plants")
- Creeping
- Climbing
- Underground
  - Rhizome; tuber; bulb

Structure
- Epidermis
  - Lenticels; (hairs, spines, etc.)
- Cortex
- Pith
- Fibrovascular structures
  - Fibers (mechanical support)
    - Wood; bast
  - Vessels (conduction)
    - To leaves (wood; xylem)
    - From leaves (bast; phloëm)
- Growing areas
  - Growing points (buds)
    - Terminal; lateral (at nodes)
  - Cambium layers (in internodes)

Functions
- Communicating between leaves and roots
- Raising leaves
- (Raising flowers and fruits)
- Propagation
- Storage of reserve food

4. Circulation of sap
- Ascending currents
  - Composition
    - Water
    - Dissolved salts
  - Drive
    - (Osmosis in roots)
    - (Capillarity through vessels)
    - (Transpiration from leaves)
  - Channels
    - Root hairs through cortex of root (by osmosis)
    - Xylem vessels of root, stem, leaf
    - Leaf vessels to pulp cells (by osmosis)
- Descending currents
  - Composition
    - Dissolved food material from leaves
  - Drive
    - (Probably osmosis and gravity)
  - Channels
    - Leaf cells into phloëm vessels
    - Phloëm vessels to growing regions of stem (cambium and buds) and of root (cambium and growing points)
    - Phloëm vessels to flowers (fruit, seed)
    - Phloëm vessels to accumulation tissues of stem and root

5. Uses of leaves
   - Direct
     - As food
     - As fodder for cattle
     - As humus and mulch
     - As source of specific materials in certain plants
   - Indirect
     - Source of nearly all human food, and, in fact, of nearly all organic matter that we use, including our own bodies
6. Uses of roots
   - As food and fodder; specific drugs etc.: propagation
7. Uses of stems
   - As food (potato, sugar cane, sago, etc.)
   - For fibers
   - For drugs, gums, resins, dyes, tanning material
   - For wood and cork
8. Food-making in simple plants
   - Essential organs (chlorophyl organs)
   - Sources of material
     - Water; carbon dioxid; (salts)
   - How materials are obtained
9. Our dependence upon sunshine

QUESTIONS

1. In what sense does life depend upon the destruction of (the living being's own) protoplasm?

2. In what sense does life depend upon destruction of other living things?

3. How can life be destroyed without making for more life?

4. What are the inorganic materials from which carbohydrates originate? What is the source of each?

5. How can we show that light is necessary for photosynthesis?

6. How can we show that carbon dioxid is essential to photosynthesis?

7. How can we show that oxygen is given off during photosynthesis?

8. How do mushrooms and other non-green plants get their food?

9. What organic materials in a plant or animal are not produced by photosynthesis?

10. What organic substances are there in your body (or in any other organism) that are not nutrients?

11. How does a leaf get carbon dioxid to its chlorophyl cells? water?

12. What parts of a leaf are not directly concerned with food-making? What relation have these parts to the life of the plant?

13. How is the root of a plant related to food-making?

14. How does a root grow in length? in thickness? What is the source of the growth material?

15. How is the stem of a plant related to food-making?

16. How does a stem grow in length? in thickness? What is the source of its growth material?

17. What use can we make of the fact that chlorophyl disappears from plant cells in darkness?

18. What use can we make of the fact that chlorophyl transforms light into heat that may "scorch" the leaf?

19. What use can we make of the fact that plants accumulate surplus food in leaf, in stem, or in root?

20. What use can we make of the fact that various parts of a plant may replace missing organs and form a complete plant?

21. What use can we make of the fact that, in spreading out toward the light and air, plants develop various mechanical structures?

22. What use can we make of the fact that in the course of their activities plants produce a variety of substances that are neither nutrients nor mechanical supports nor protection?

23. How can we tell that living leaves give off water?

24. How can we tell that matter from the soil travels through a plant along different channels from those followed by food sap?

REFERENCE READINGS

Bergen and Caldwell. Practical Botany, pp. 15–20, 55–71.

Osterhout, W. J. V. Experiments with Plants, pp. 180–203; chap. v, The Work of Stems.

Densmore, H. D. General Botany, chap. vi, The Structure and Functions of Stems, Roots, and Leaves; pp. 117–124, 142–146.

Gaye, Selina. Why Plants need Water (extract in C. H. Ward's "Exploring Nature," pp. 69–74).

CHAPTER XI

HOW FOOD IS TAKEN IN

Questions. 1. How does a cell distinguish between what it may take in and what may be injurious? 2. How do roots select the soil materials that they can use? 3. Why does not the substance in a root hair or other living cell go out into the soil or water? 4. How can living things without mouths take in food?

99. Diffusion. Illuminating gas and the vapors of odorous substances spread through the air very rapidly, by a process called *diffusion*. Diffusion takes place also in liquids. Salt or sugar left in the bottom of a vessel of water is gradually dissolved, lifted from the bottom, and distributed to all parts of the liquid, overcoming gravity. Diffusion therefore represents work, or the expenditure of energy. This attraction between water and certain kinds of substances helps us to understand what happens in roots and in other parts of living things.

100. All cells absorb. In many one-celled animals, like *Ameba*, the protoplasm is said to be naked, since there is no permanent cell covering or wall. In most plants and animals the protoplasm of each cell is more or less completely inclosed by a membrane of non-living material. We know that the root is capable of absorbing material from its surroundings and that the many cells inside every plant or animal, away from the surface, all absorb their water, food, and oxygen through the cell wall, yet a powerful microscope fails to show any openings through the cell walls, or even between adjoining cells. The substance which makes up the cell walls in most plants is called *cellulose*. This substance cannot dissolve in water, but it can absorb water in the same way as glue or gelatin. Now water can diffuse through cellulose, although the cellulose cannot dis-

solve or diffuse. Substances that dissolve in water can thus diffuse through a cell wall as long as the cellulose is full of water.

101. Diffusion through a membrane. When solutions of two different substances are separated by a layer of cellulose or gelatin, they may diffuse through the water contained in the separating membrane. In this way they may diffuse through the membrane itself. Such diffusion is called **osmosis**. This process takes place in the walls of cells, since the watery liquids on the two sides of such a membrane are not the same. Thus there is a double current: protoplasm receives from the outside its supply of water, salts, and food, and materials in the cell pass out. Gases as well as liquids diffuse through the wet cell wall.

102. Osmosis in living things. The cell wall of a root cell separates the protoplasm from the surrounding soil water. Income through the root hair is therefore by diffusion through the cell wall, or by osmosis. But the protoplasm within the cell wall is not a uniform mass of substance, and diffusion takes place between one part and another.

Some substances dissolve in water more easily than others. Some of the common solids do not dissolve at all. Of those that can dissolve in water and diffuse, some will diffuse more quickly through cell walls than others, and some will not pass through at all. Of the substances that can diffuse through cellulose, some can diffuse through protoplasmic membranes more quickly than others, and some cannot diffuse through such membranes at all. As a result of these differences, cells exposed to the same material surroundings may not be equally affected.

Living things absorb materials from the outside world by osmosis. Within the body of every plant and every animal consisting of many cells, materials also pass from cell to cell, or between cells and various body juices, by this process.

103. Plant income. Green plants, as we know, manufacture their food out of raw material—water, carbon dioxid, and various salts. Water is readily absorbed by cellulose. Through the cell walls saturated with water, carbon dioxid from the air and salts from the soil pass by diffusion, or osmosis. Within the

plant these substances pass from cell to cell, or through special vessels or spaces. Leaves are particularly well fitted to absorb gases from the air and to pass gases into the air (see Fig. 61 and Fig. 64). Roots are generally well fitted to absorb water and dissolved salts from the soil, the surface being greatly enlarged by the outgrowth of **root hairs** (see Fig. 66).

104. Animal income. The sugars are the only nutrients that can dissolve in water. Starches and proteins, while capable of absorbing water, cannot dissolve. Such substances are called *colloids* (which means "like glue"), to distinguish them from sugars and salts, called *crystalloids*, which can dissolve in water and diffuse through cellulose and other membranes. Moreover, most of our food consists not of pure sugars, starches, and proteins, but of plant and animal tissues the nutrients of which are locked up in cells. Finally, seeds, stems, and other portions of many plants contain colloid starch, which we have considered as food for the growth of the plant. How can plant and animal cells make use of such colloids?

105. Digestion. Experiments show that colloids can be changed into crystalloids; and then the material can pass through cell walls by osmosis. The process of transformation is called **digestion** and can easily be demonstrated.

In the grains and in seeds containing starch the absorption of water leads to the development of a substance called **diastase.** This can convert starch into sugar. Diastase has been extracted from malted barley (that is, barley kept moist until the grains have sprouted), from rice, and from many other seeds. It can now be bought in the stores. A substance that behaves in many ways like diastase is found in human saliva (spit) and in the digestive juices of many other animals.

Substances like diastase and the active part of the saliva are called **ferments**, or **enzyms**, and many different kinds are known. They are peculiar in that *they seem to induce chemical changes in other substances, without, however, undergoing any changes themselves.* As a result of this peculiarity a comparatively large amount of material may be made to undergo chemical change through the activity of a very small amount of enzym.

106. Digestion universal. Digestion seems to go on in nearly all living things. In the ameba, which consists of a single cell (see section 47), a solid particle of food can be swallowed by the naked protoplasm and then digested inside the cell. Among the bacteria, which are the smallest living things known, each individual is a single cell consisting of protoplasm and cell wall. These tiny plants can get food only in a liquid state, yet many of them live on solid food that is not soluble in water. Under suitable external conditions each cell throws out through the cell

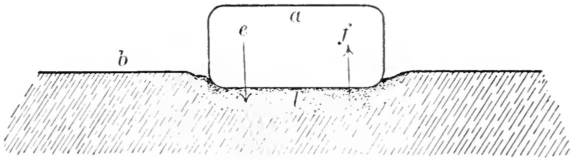


Fig. 73. Digestion by bacteria

The organism, *a*, lying on a solid, *b*, which may serve as food, secretes an enzym, or ferment, which passes out of the cell, *e*, and changes the material to a liquid, *l*. This is absorbed into the cell by osmosis, *f*

wall, by osmosis, a liquid containing a ferment capable of digesting the solid, or insoluble, food material. The liquid resulting from the digestion is then absorbed by osmosis. This is why meat or cheese becomes fluid when it rots. The rotting in such cases is the work of the ferments contained in the digestive juices given off or secreted by the bacteria (Fig. 73). In higher animals like ourselves a similar process of digestion takes place; but instead of every cell's pouring out digestive juices into its immediate neighborhood, only certain portions of the body produce and throw out such juices.

HOW FOOD IS TAKEN IN

1. Diffusion
    - Materials capable of diffusion
        - Gases; liquids; solids in solution
    - Conditions in which diffusion can take place
        - Free contact of diffusible substances
        - Certain kinds of membranes (semipermeable)

2. Osmosis
   - Meaning of osmosis
   - Osmosis in living things
     - Into cells; out of cells; within cells

3. Absorption in organisms
   - Root absorption
     - Materials
     - Organ
     - Relation to life of plant
   - Leaf absorption
     - Where it takes place
     - What is absorbed
     - Relation of absorbed material to life of plant
   - Absorption in one-celled organisms
     - What is taken in
     - How material is taken in
     - Relation of intake to life
   - Absorption in larger animals

4. Digestion
   - Character of change
   - Importance to living things
   - How brought about
     - Enzyms; ferments

QUESTIONS

1. What practical use do we sometimes make of the fact that gases diffuse readily?

2. What would be the condition of our atmosphere if the different gases in it did not diffuse?

3. What substances swell in water without dissolving?

4. Why will ink spread on wet paper but not on dry?

5. Why does the protoplasm inside a cell shrivel or shrink up when the cell is placed in salt water?

6. Will a root or a sausage shrink or swell in salt water? Why?

7. Under what conditions will a cell absorb more than it gives out?

8. Under what conditions will a cell give out more than it absorbs?

9. How can animals make use of solid food? How can plants?

REFERENCE READINGS

Bergen and Caldwell. Practical Botany, pp. 7–9.
Osterhout, W. J. V. Experiments with Plants, pp. 121–124.
Densmore, H. D. General Botany, pp. 137–142.
Fabre, J. The Glowworm's Anæsthetic (extract in C. H. Ward's "Exploring Nature," pp. 101–107).

CHAPTER XII

WORKING OVER THE BODY'S INCOME

Questions. **1.** What happens to food after it is eaten? **2.** How does the food which we place in the mouth and swallow get to the other organs of the body? **3.** What connection is there between the stomach and the other inside organs? **4.** Why are some kinds of food more easily digested than others? **5.** What causes indigestion?

107. The human food tube. The mouth is the beginning of a long tube inside of which all the digestion takes place. This tube is called the *food tube*, or **alimentary canal**. It consists of several fairly distinct regions. It gets to be ten or eleven yards long and is coiled or twisted in parts (see *j*, *k*, Fig. 74).

108. Mouth digestion. After the food enters the mouth it is crushed and ground by the teeth. The taste of the food, the movement of the jaws, and the rubbing of the food against the inside of the mouth stimulate the **saliva** glands, that is, set them in action (see Fig. 75). As a result a quantity of saliva is poured into the mouth and becomes mixed with the food. The action of the saliva upon the starch changes it into sugar (see section 105). The other materials in the food are probably not changed, except that salts and sugars are dissolved in water, of which the saliva contains over 99 per cent.

As the amount of ferment is very small, the effectiveness of saliva in digesting starch depends upon (1) the ferment's reaching every particle of starch, and (2) its having sufficient time to act. Mixing saliva thoroughly with the food makes it easier for the mass to slide along into the throat, and down the gullet, since the mass is thus coated with the slippery *mucin* of the saliva.

109. Swallowing. After the mouthful of food has been thoroughly chewed, it is pushed back by the tongue and passed into the throat chamber, or **pharynx** (see *b*, Fig. 74), from which it

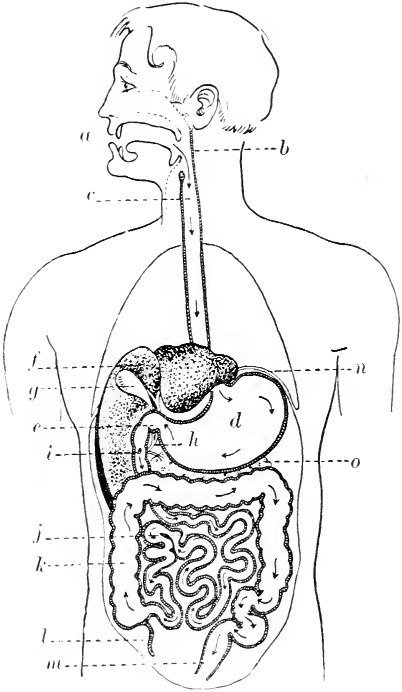


Fig. 74. The digestive organs in man

a, entrance to mouth; *b*, the pharynx — a sort of vestibule with seven passages leading out of it, two to the nostrils, one to the mouth, one to the gullet, one to the windpipe, and one to each ear (the Eustachian tubes, see Fig. 115); *c*, the gullet, or *esophagus*; *d*, the stomach; *e*, the *pylorus*, opening from the stomach to the small intestine; *f*, the liver; *g*, the gall bladder; *h*, duct from the gall bladder and the liver to the small intestine; *i*, duct from the pancreas to the small intestine; *j*, small intestine; *k*, large intestine; *l*, vermiform appendix; *m*, rectum; *n*, the diaphragm, separating the chest cavity from the abdominal cavity; *o*, the pancreas. The arrows indicate the course taken by food

passes directly into the gullet, or **esophagus.** In the wall of the gullet is a series of muscular rings which contract one after another, carrying the food toward the stomach. If you watch a horse drinking water from a pond or from a pail on the ground, you can see him swallow *up*; and you can see one wave of contraction after another pass along the gullet, from the head to the trunk.

110. The stomach. The fermentation started in the mouth continues in the mass of food until it gets into the stomach. Here it is stopped when the acid, or sour, stomach juice comes in contact with the saliva. The swallowed food is thoroughly mixed with the **gastric, or** stomach, juice by the action of the muscles in the stomach wall. These muscles run in different directions; by their contractions the contents become thoroughly churned. The wall of the stomach also contains the glands in which the digestive fluids are produced (see Fig. 76).

The peptones resulting from stomach digestion differ from proteins chiefly in being soluble in water and capable of diffusing through membranes. As the changing of proteins into peptones goes on, the mixture in the stomach becomes more and more liquid and more and more acid. From time to time a quantity of the liquid passes into the intestine. After a while most of the contents of the stomach has been changed to a mixture having the consistency of a rather thick pea soup, and all of it has passed on into the intestine.

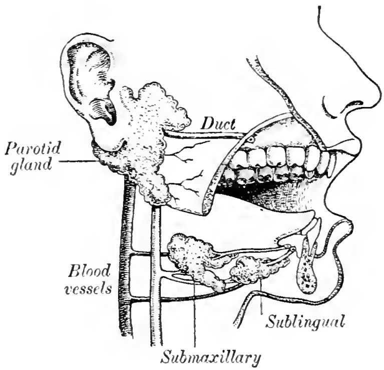


Fig. 75. The salivary glands

There are three sets of glands which produce saliva: the parotid, in the cheek, just in front of the ears; the submaxillary, under the angles of the jaw; and the sublingual, under the tongue. The more the food is chewed, the smaller are the particles into which it is broken, and the more thoroughly is the saliva mixed with these particles

111. The bowels or intestines. Among the highest animals the gut has two distinct divisions. The first is called the **small intestine**, and in human beings it is about one inch in diameter and about twenty-four or twenty-five feet long. This opens rather abruptly into the **large intestine**, which is about two inches in diameter and about five feet long (see *j*, *k*, Fig. 74).

You have probably handled a piece of pig gut or calf gut, which is used as sausage casing. The wall of the intestine is thin and soft. The lining carries very small glands, and the outer layer contains muscle cells. The muscle cells are arranged in rings; when they contract they simply reduce the diameter of the intestine at any given point. The contraction starts at the forward end (nearest the stomach) and passes backward along the whole length of the small intestine, aided by longitudinal muscles. As a result of these contractions some of the thick mixture of food and digestive juices is moved along,

a short distance at a time. This movement is called **peristalsis** and is similar to the swallowing movement of the gullet. In vomiting, this peristaltic action of the food tube is reversed.

Neither the saliva ferments nor the gastric ferments have any effect upon fats. When a food mixture passes from the stomach, it contains all the sugar that was there to begin with, all the sugar that was formed by the digestive action of the saliva, and whatever starch was not digested. It contains the peptones resulting from the gastric digestion, and particles of proteins that were not digested. In addition there is a quantity of water, mineral salts, the remains of the gastric and salivary juices, and the fibers and cell walls of the food material. In the intestines further changes take place.

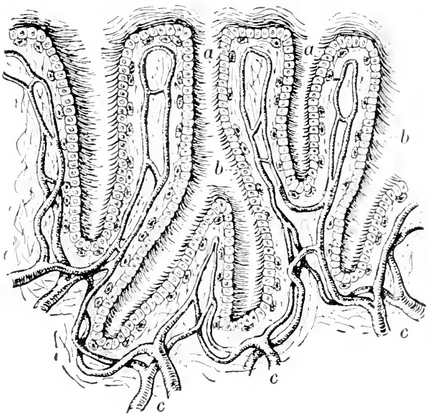


Fig. 76. Glands of the stomach

The gastric juice is poured into the stomach through tubes, *a*, which are lined by a layer of delicate cells; it is produced by special gland cells, *b*, from materials brought by the blood in fine vessels, *c*. The stomach juice contains, in addition to an acid, a special ferment, *pepsin*. In the presence of acids pepsin acts upon proteins and changes them into soluble *peptones*

Near the beginning of the intestine two small tubes, or **ducts** (*h*, *i*, Fig. 74), empty at a common opening. One of them leads from the largest gland in the body, the **liver**; the other from another important gland, the **pancreas** (see *o*, Fig. 74).

112. The pancreas. The juice secreted by the pancreas contains three important kinds of ferments:

1. A ferment that converts starch into sugar.

2. A ferment that digests proteins into simpler compounds.

Any starch that has been swallowed before the saliva has had time to transform it into sugar, and any protein that has passed

from the stomach without being digested by the pepsin, will now be digested by the action of the pancreatic ferments.

3. A ferment that breaks up fats into *glycerin* and fatty acids. The latter combine with other substances to make *soaps*. Soaps and glycerin dissolve in water and diffuse through the cell walls. Pancreatic juice thus contains the ferments necessary for digesting all nutrients.

113. The liver. This produces **bile** or gall.

1. Bile contains no digestive ferments, but it does influence the absorption of the fatty acids and soaps by the cells of the intestine.

2. The bile seems to have some effect upon the activity of the pancreatic ferments. When the contents of the stomach pass into the intestine, the mixture is acid. The bile neutralizes the acid and makes possible the activity of the other ferments.

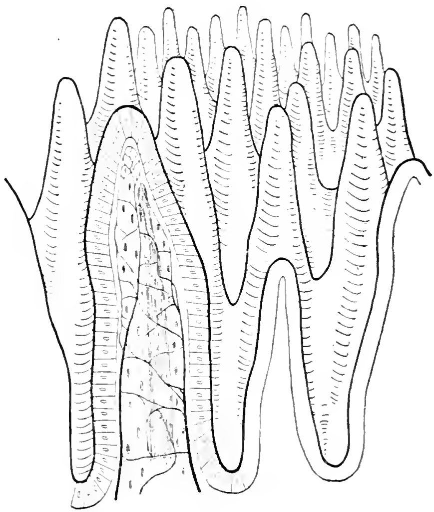


Fig. 77. Lining of the intestine. (× 150)

The tiny projections from the lining of the small intestine, the *villi*, give the appearance of very fine velvet. Absorption takes place through the outer layer of cells. Within each villus are fine blood vessels and lymph spaces; from these the absorbed food is transferred to the circulation system. Chemical changes take place in the course of the transfer. As a result the material taken into the blood is not exactly the same as that absorbed from the intestine, although it is made up of the same elements

3. The bile is made up chiefly of materials that are of no further use to the body; the liver is thus also an excretory organ.

114. The intestinal juices. The juices secreted by the glands of the intestine contain no ferments of great importance in digestion, but they neutralize the acids resulting from various chemical changes in the gut. One ferment in the intestinal juice converts cane sugar into simpler sugars.

115. Absorption. Very small outgrowths project into the cavity of the small intestine, so that the surface exposed to contact with the food mixture is increased several hundred times. Each of these tiny projections, called a **villus** (plural, *villi*) (see Fig. 77), acts as a special absorbing and transforming organ. The mixture in the intestine now consists of (1) many

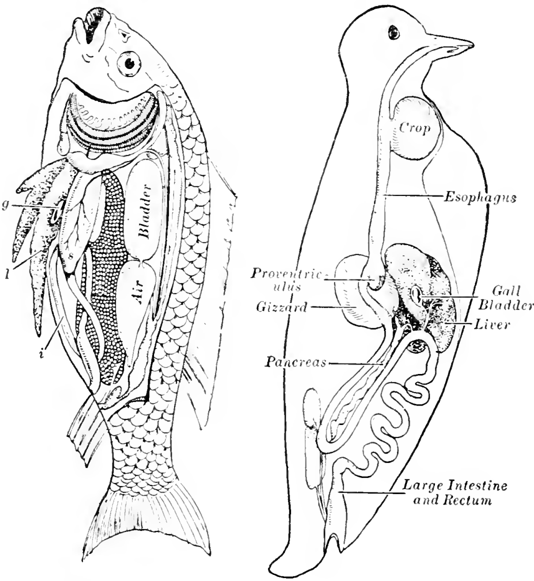


Fig. 78. Digestive system in fish and in bird

The main features of the digestive system are alike in all backboned animals. In the birds the gullet has a curious pouch, the crop, in which food may be retained indefinitely and later either swallowed to the stomach or regurgitated through the mouth. The glandular portion of the stomach, or *proventriculus*, is distinct from the grinding part, or gizzard

crystalloids in solution, (2) many colloids in the process of being converted into crystalloids, and (3) solid substances that are not capable of changing under conditions that exist in the gut.

When the dinner that you have eaten reaches the end of the small intestine, most of its carbohydrates, proteins, and fats have been absorbed by the villi and passed into the blood and

lymph. There is left in the intestines chiefly (1) the undigested (mostly indigestible) fibrous and cell-wall parts of the plant or animal tissues eaten, and (2) the modified secretions of the various glands that have poured into the food tube along the way. This mass of refuse now passes into the large intestine (*k*, Fig. 74).

116. The large intestine. In the large intestine the ferments of the digestive juices may continue to act for some time. Gradually, as the mass proceeds along the canal, it becomes drier as the lining of the intestine continues to absorb fluids (there are no villi in the large intestine). Toward the end the only chemical changes going on are those produced by the millions of bacteria that are present in the intestines of all animals that have intestines.

The mass of material that has accumulated toward the end of the large intestine is of no further use to the body, and should be removed from time to time (see section 131). Birds, having no large intestines, throw off the refuse about as fast as it passes from the small intestine to the rectum (Fig. 78). Other animals and human infants throw off the refuse automatically.

WORKING OVER THE BODY'S INCOME

1. The digestive tube of man
    - Mouth (organs related to nutrition)
        - Teeth; salivary glands; (tongue)
    - Pharynx (seven openings)
        - Mouth
        - (Windpipe)
        - (Eustachian tubes, 2)
        - (Nostrils, 2)
        - Gullet (*esophagus*)
    - Gullet
        - Swallowing muscles
    - Stomach
        - Gastric glands; muscles
    - Small intestine
        - Glands; muscles; villi
        - Connection with liver and gall bladder
        - Connection with pancreas
    - Large intestine
        - Connection with small intestine
        - (Vermiform appendix)
        - Rectum

2. Digestion of nutrients in the human body
   - Starch changed into grape sugar
     - Saliva (ptyalin); pancreatic juice (amylopsin)
   - Protein changed into peptones and amino acids
     - Stomach juices (pepsin; acts in acid)
     - Pancreatic juices (trypsin; acts in alkali)
   - Fat changed into glycerin and fat
     - Pancreatic juice (steapsin)
   - Cane sugar changed into grape sugar
     - Intestinal juice
3. Absorption
   - Villi of small intestine — Lining of large intestine
   - Transfer to blood stream
4. Undigested refuse

QUESTIONS

1. Why cannot the cells of our body make use of the food as we receive it from the kitchen?

2. What kind of nutrient is digested by the mouth juices?

3. Why should we chew food that is not digested by mouth juices?

4. What use does the body make of the saliva secreted as a result of chewing gum if the saliva is thrown out? if the saliva is swallowed?

5. How can we show that pepsin acts upon proteins but not upon starch or fat? How can we show that pepsin acts in an acid solution but not in an alkaline solution?

6. How can we show that saliva acts upon starch but not upon protein?

7. How can we show that crystalloids will pass through the wall of the intestine but that colloids will not?

8. Why is it important to prevent accumulation of refuse in the large intestine for a long period?

REFERENCE READINGS

Bergen and Caldwell. Practical Botany, pp. 144–145.
Osterhout, W. J. V. Experiments with Plants, pp. 155–178.
Densmore, H. D. General Botany, pp. 124–130.
Hough and Sedgwick. The Human Mechanism, pp. 99–134.

CHAPTER XIII

WHAT TO EAT

Questions. **1.** Why can we not safely trust our instincts in deciding what to eat or what not to eat? **2.** Why can we not always safely trust our feelings in deciding how much to eat? **3.** Why can we not always depend upon the customs of people in deciding how much to eat or what kinds of food are good?

117. Why eating must be learned. We should expect that in half a million years or more the human race might have learned all there was to know about what to eat and how to eat it. Most people, however, do not know, either from instinct or from daily experience, the best way to manage their personal food problems. Everywhere children suffer from defective nutrition and grown folks from disturbances of digestion. Starvation and overfeeding exist side by side.

Although all living beings consist fundamentally of proteins, fats, and carbohydrates, not all plant or animal stuff is suitable for food. Some plant and animal materials are not pleasant to the taste, or are even disagreeable, and others are *poisonous*; and some contain too little usable or digestible substance to be worth eating. In the course of ages human customs have selected the plant and animal materials *in any given region* that are most valuable as food. We know that some parts of animals and plants (muscle, grain) are better than others (hide, wood); but experience has not taught us what *proportions* of meat and grain and fruit are the best for bodily comfort and efficiency, and we still have to learn that one combination is best for one person, and another combination for others. With the increase in travel, communication, and transport we are constantly discovering useful food plants and food animals, and neither our instincts nor our customs tell us the best way to use them.

118. Food and health. All the chemical changes and activities that are constantly going on in living protoplasm are called **metabolism.** Some of these processes are constructive, leading to the formation of new protoplasm and tissues. Other changes are destructive, resulting in the breaking down of proteins and other complex substances. The activity of the protoplasm during the rest or sleep of the body is fairly constant, and is called the *basic metabolism.* We can measure the metabolism or activity in an organism by measuring the amount of *heat* that the body gives off, since all the chemical and mechanical processes end in this form of energy. Even the cold-blooded animals and plants give off heat.[1] Now the first function of food is to supply the materials used up in metabolism—proteins and fuels (fats and carbohydrates)—in proportion to the daily needs of the body. These needs vary with the basic metabolism and with the amount of external work done. Two men of the same weight have about the same food requirements so long as they both keep quiet; but if one is more active than the other when not resting, he needs more food.

It is possible to determine pretty accurately (1) how much protein is needed for a growing body, (2) how much protein and fuel food is needed for basic metabolism, and (3) how much fuel food is needed for the additional work of the body.

In addition to the nutrients (see page 102) the body needs certain mineral substances (chiefly calcium, phosphorus, and iron) and supplies of vitamins (see page 102). A deficiency in protein cannot be made up by an excess of fats or carbohydrates, although fats and carbohydrates may replace each other as fuels. Vitamins, while needed in but very small quantities, cannot be excluded from the diet without bringing about serious disturbances in metabolism. In the same way, a lack of calcium may bring about softening of the bones in the case of a growing child,

[1] The unit of energy used in measuring heat is the *calorie.* This is the amount of heat that is used up in raising the temperature of a kilogram of water (a little more than a quart) from 0° to 1° C. For very delicate work the "small calorie" is used; this is one thousandth of a "large calorie."

or a defect in the milk of a nursing mother; iron must be present for the formation of the red coloring matter in the blood cells (hemoglobin); and so on. The food must contain a variety of substances, in certain proportions which vary with the age of the eater, his size, and the amount of work that he does.

119. Selecting our food. People know from painful experience how unwise it is to depend altogether upon our feelings or "instincts" in deciding the kinds and quantities of food eaten; yet our tastes and appetites deserve respectful consideration.

Taste. Most people like sweets. This does not show that all sweet things are good for us, since some are actually poisonous; but a "sweet tooth" may show that the body needs more carbohydrate than it gets regularly. On the other hand, food that is not tasty interferes with the digestion. The secretion of the digestive juices depends upon a pleasurable stimulation of the nerves connected with the nose and tongue. We all know that smelling some attractive food makes the "mouth water." In the same way, the pleasurable stimulation of certain nerves *makes the stomach water*, or secrete the gastric juices. Now while saliva can digest starch in a test tube, and gastric juice can act upon meat in a tin cup, without regard to anyone's feelings, the glands of the stomach and of the mouth will secrete juices readily only when the taste is pleased.

Appetite. A healthy body of sound habits is not likely to feel hungry except when it needs food; nor will such a body acquire either violent desires or violent dislikes for particular kinds of food. But in order to form sound habits we must have experience in recognizing just what conditions of eating and what kinds of food are best suited to us. Food may be attractive to a given person and yet be unsuitable for him because he cannot digest it. Whoever has charge of young children should discover whether each kind of food is suitable for each particular child, or whether the child is acquiring unreasonable prejudices toward particular kinds of food. Later each one of us has to continue his own education. No person or book can tell you whether shrimp or cheese will agree with you; you have to find

out for yourself with respect to every kind of food, and then use your knowledge. You will have to find out how much you can best eat at one time, or how often you have to eat.

Digestibility. Aside from individual peculiarities of the digestive system, some foods are more easily digested than others. For example, milk contains the proteins, fats, carbohydrates, and salts in a very easily digested form. Meat proteins and fats are in general more easily digested than vegetable proteins and fats; but the meat proteins are inclosed in materials that may not be so easily digested.

Nutritive value. We usually know immediately whether our food pleases us, or whether we have stopped our hunger; and if something goes wrong with the digestion, we soon discover it. But we may continue a very long time on a diet that is seriously lacking in essentials without realizing it. For this reason we must see that everybody acquires tastes and habits guided by reliable knowledge of daily needs. Such knowledge rests upon studies of what people do actually eat, and upon experiments with the diet and its effects on college students, soldiers and other people, and on various animals. Some of these experiments are made with a very elaborate and very accurate apparatus called the respiration calorimeter (see Fig. 79).

120. Daily needs. From these studies and experiments it has been possible to make out tables of daily needs for men and women, boys and girls, at different ages, in different occupations, at different seasons of the year. The age is important because (1) the digestive system of a young person may not be able to tolerate what an older person can stand; (2) a young person is usually smaller and so uses up less proteins in the basic metabolism each day; and (3) the young person is still growing, and so uses up more proteins for building new tissues than does the older person. The occupation is important because the amount of energy used up in the day's work must be supplied by the fats and carbohydrates, in addition to the nutrients required for the basic metabolism. So in the winter we need more fuel to keep up the body temperature.

121. Nutritive ratio. It would be possible for a person to subsist on a protein diet, since these nutrients are also oxidized in the cells, and yield energy; and many animals and some plants do actually get along on proteins alone. But a surplus of protein puts an additional burden upon our livers and

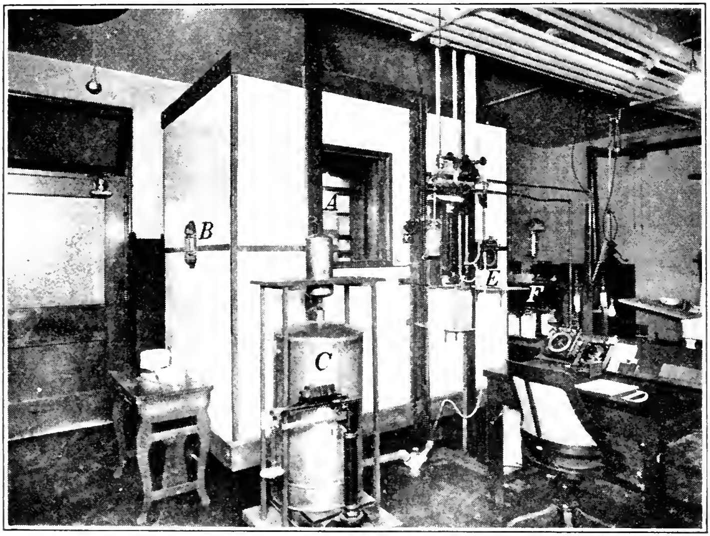


Fig. 79. The respiration calorimeter

In the large chamber a man can live for several days or weeks under conditions that give an accurate account of his body's income and expenditure, in the way of matter as well as in the way of energy. *A*, door and window; *B*, door for food etc.; *C*, tank for catching water circulating through the walls of the chamber; *D*, observer's table, with devices for measuring and regulating temperature etc.; *E*, rubber bag to equalize the air pressure within the chamber; *F*, apparatus for circulation and purification of air in the chamber. (From photograph furnished by Office of Home Economics, United States Department of Agriculture)

kidneys, besides being relatively more expensive financially. It is really worth while to reduce the protein in food to the lowest proportion of practical safety. This proportion of protein in the diet is called the *nutritive ratio*. In countries which have relatively cheap supplies of meat there has been a tendency to consume an excess of proteins. The best studies we have point

to a daily consumption of about three ounces of protein as being *safe* from a health point of view, and at the same time *abundant* to meet the needs of metabolism and growth.

122. Age and diet. If we take the food required by a man of about 150 pounds weight, doing moderately hard work, such as a weaver or a bookbinder, as one hundred, the amounts needed by children at different ages are about as follows:

Age	For Boys	For Girls
Under 2 years	30	30
2 to 5 years	40	40
6 to 9 years	50	50
10 to 12 years	60–70	60
13 to 14 years	80	70
15 to 16 years	90	80

The nutritive ratio is left the same for children as it is for adults, although growing children need more proteins. The balance is brought about by the fact that the children are more active than adults and use up comparatively more fuel. Indeed, some students of the problem would give boys and girls of high-school age more food than hard-working adults. This agrees with the fact that at this period many of us seem to be always eating, or at any rate always hungry. The basic metabolism is known to be greater at this period, so it is likely that we shall have to correct our figures upward.

123. Work and other conditions. Experiments made to show the quantity of energy used up by a man under varying conditions gave the results summarized in this table:

Condition of the Body	Calories per Hour
At rest, sleeping (corresponds probably with basic metabolism)	65
At rest, awake, sitting up	100
At rest, standing	117
Engaged in light muscular exercise	170
Engaged in moderately active muscular exercise	290
Engaged in severe muscular exercise	450
Engaged in very severe muscular exercise	650–675

Since we do not sleep all the time or work all the time, the amount of energy used up per day will depend upon one's daily program. Thus, a person working in the steel mills twelve hours a day, seven days in the week, expends more energy than a clerk who sits at a desk eight hours making out pay rolls. The energy needs of various classes of workers are given in the following table, which combines the results of many different studies:

Classes of Workers	Calories per Day
Woodcutter, lumberman	5000–6000
Stonecutter, excavator, miner	4700–5000
Farmer, cabinetmaker, painter	3500–4000
Metal worker, mechanic	3400–3500
Carpenter	2700–3400
Weaver, bookbinder, tailor, shoemaker	2500–3200
Business man, student	2400–3000

Studies made in Finland with the respiration calorimeter give the following table on the needs of women workers:

Classes of Workers	Calories per Day
Washerwoman	2900–3700
Housemaid	2500–3200
Bookbinder	2100–2300
Seamstress (on sewing machine)	2100–2300
Seamstress (on hand work)	2000

124. Climate and seasons. We know that the natives of tropical countries eat very little meat, and that the natives of cold countries eat very little fruit but a great deal of fat. We can understand why the Eskimos eat no fruit; but the inhabitants of the tropics can get almost any kind of food they wish. The fact is, however, that in a cold region it is necessary to provide for a larger supply of body heat than in a hot region. Since fat yields the greatest amount of energy for a given weight of fuel,[1]

[1] The fuel values of proteins, fats, and carbohydrates are as follows:

	Calories per Gram	Calories per Pound
Proteins	4.1	1860
Carbohydrates	4.1	1860
Fats	9.3	4219

it is especially desirable in the diet when energy output is needed rather than building material or bulk. Accordingly we may increase the proportion of fuel in the winter, eating more fat, and reduce it in the summer.

125. Food composition. How can we translate the products of the food factories and the kitchen into terms of proteins and

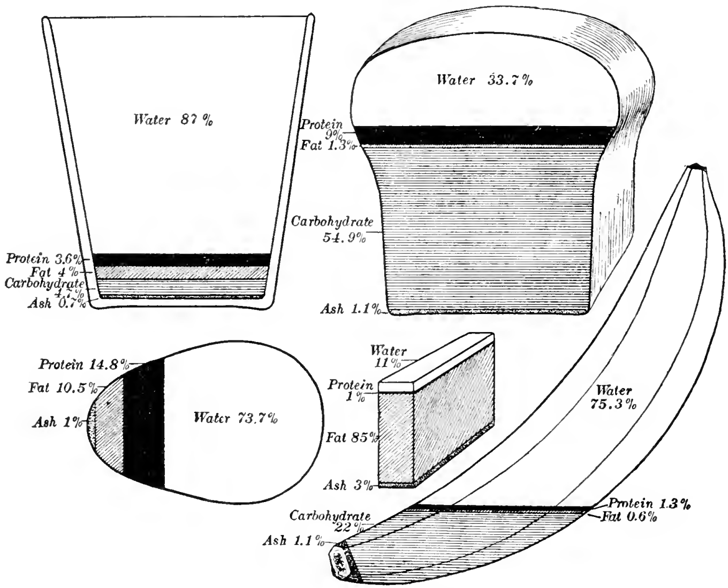


Fig. 80. Composition of food

The proportions of water, protein, fat, carbohydrate, and mineral matter (ash) in a glass of milk, an egg, two slices of bread, a pat of butter, and a banana are shown in this diagram, designed after the Langworthy charts. Such diagrams enable us to tell at a glance the relative amount of each nutrient present in our common articles of diet

calories and vitamins? The means for such translation is furnished by tables that have been prepared by various experts working for the government, for hospitals and other institutions, and for manufacturers. We can make use of the results obtained by these experts to guide us in our own selection of food. From the diagrams in Fig. 80 we can see that some of the

food material which we use contains more nutrients than others. We also know that they contain varying proportions of proteins, fats, and carbohydrates. Mr. Frank A. Rexford of Brooklyn has prepared a convenient table (see page 149) which shows the composition of an ordinary helping of various food articles, giving (1) the usual quantity, (2) the amount of protein, fat, and carbohydrate that such a helping contains, and (3) the amount of energy it yields.

126. Balanced diet. The practical thing about diet is that the food taken shall be (1) sufficient in amount to yield the needed energy; (2) suitable in composition to yield about three ounces of protein per day; (3) of a composition containing the needed vitamins and minerals; (4) palatable for the person who is to eat it; (5) adapted to the digestion of the individual.

Each of us must find out for himself what foods will suit our taste and the digestion. A good rule is to learn to eat all kinds of food, so as to be able to meet all circumstances. Now fuel value, the proportion of protein, and the various kinds of vitamins and minerals depend upon the composition of what we eat. From the table on page 149 we see that broiled chicken contains about three quarters of an ounce of protein to an ordinary helping of about three and a half ounces. Four such portions a day would supply enough proteins, but less than 500 calories of fuel value; and enough chicken to supply the necessary fuel would furnish a large excess of proteins. On the other hand, if you tried to live on fruit, you would have to eat the equivalent of from thirty-five to fifty pounds of apples to supply the necessary protein, although nine or ten pounds would supply the necessary fuel, in the form of sugars.

Most of the animal foods have an excess of proteins, whereas most of the foods of vegetable origin have a relative shortage of proteins. In order to get a satisfactory diet that meets all the conditions, it is most convenient to mix our rations. By using food of various kinds we can get a balance combined with bulk and taste. For children under one year of age, milk alone can be made to serve.

Uninformed people are in danger of taking food entirely on the basis of their taste or the temptations of the market. They are likely to suffer from malnutrition through an excess of sweets or from digestive disturbances through an excess of proteins. People who are both ignorant and poor are in danger of getting their food altogether on the basis of its cost, and suffer from malnutrition through an excess of starchy food, which is usually the cheapest.

127. Food fads and notions. That the race has not yet learned what is best for it in the way of eating is shown by the widespread interest in new food fads, and the great variety of notions about food. There is frequent discussion about flesh food versus vegetable food, with all sorts of arguments that have little to do with real facts. For example, one hears that it is "wrong to kill living beings to maintain our own lives" or that "we become what we eat." If we understand the basic facts of nutrition, we realize that all our food must come from "living beings," and that, with the exception of green plants, all living beings, including ourselves, must depend upon other living beings for their food. In his ignorance the savage may believe that eating the heart of his enemy will give him the courage of his enemy, or eating the flesh of an ox will give him the strength of an ox. But we have learned that all the food we eat, no matter what its source, must first be converted into amino acids and simple sugars before it is taken into the protoplasm of our own cells. And we have learned that these sugars and amino acids are built up into *human protoplasm.*

A well-balanced diet, obtained by means of a variety of food articles, is likely to supply the needed minerals (see page 101), as well as the necessary vitamins (see page 102), and it is likely also to be of sufficient pleasure to the palate to insure suitable activity of the digestive glands. The best arguments in the matter of eating are based on facts, and the most reliable facts that we have at present are derived from systematic scientific experimentation. Everybody who takes a little trouble can get the full benefit of the results for his own practical use.

PART OF MR. REXFORD'S ONE-PORTION FOOD TABLE

	Weight of Ordinary Helping (Ounces)	Ounces of Protein	Ounces of Fats	Ounces of Carbo-hydrates	Calories Furnished
Milk, whole	6.0	.19	.24	.30	123.6
Buttermilk	6.0	.18	.03	.29	61.9
Butter	0.5	.05	.43		112.5
Cheese, full cream	1.0	.26	.34	.02	122.4
Eggs, boiled (2)	4.75	.64	.50		227.1
Beef, sirloin	2.25	.37	.36		137.1
Beef, chuck, lean	3.0	.57	.4		172.5
Beef, dried	1.0	.26	.07		49.4
Bacon	1.0	.1	.66		188.6
Ham, lean	2.25	.49	.55		203.2
Lamb, leg	3.5	.67	.44		194.3
Chicken, broiled	3.5	.75	.09		110.5
Salmon (canned)	2.0	.44	.24		114.1
Brook trout	1.75	.33	.36		135.9
Oysters	3.5	.21	.04		36.4
Bread, white, homemade	2.0	.18	.03	1.07	153.1
Oatmeal	4.25	.13	.02	.49	76.5
Macaroni, boiled	2.75	.36	.02	2.00	286.2
Beans, baked	3.25	.31	.18	1.08	182.0
Cabbage, boiled	4.00	.03	.09	.06	35.2
Potato, boiled	3.00	.08	.01	.73	82.8
Apple, fresh	5.5	.02	.02	.78	99.6
Banana	3.5	.05	.02	.77	100.8
Dates	1.75	.04	.05	.59	177.6
Figs	2.0	.09	.01	1.5	184.4
Orange	5.0	.04	.01	.58	75.0
Peanut	0.5	.13	.19	.12	80.1
Walnut, English	0.5	.08	.32	.08	103.4
Sugar	0.25			.25	27.0

WHAT TO EAT

1. Why choice of food must be learned
   - Our instincts are not related to the usefulness or the harmfulness of the many things that we can put into our mouths
   - There is no necessary connection between the food value of natural objects and their appearance or taste
   - There is no necessary connection between contents of natural objects and their possibly poisonous properties or their digestibility
   - New plants and animals of food value are constantly being introduced from other parts of the world
   - New discoveries are constantly being made about the relation of natural materials to the health of the human body
   - New discoveries are being made about the influence of cooking, preserving, etc. upon the food value and effects of natural materials
2. Relation of food to health
   - Upkeep of basic metabolism
   - Supply of growth material
   - Energy for day's work
   - Vitamins and mineral activators and regulators
3. What should influence selection of food (quality)
   - Taste; digestibility; nutritive value
4. Daily needs (quantity)
   - Nutritive ratio (about 11 per cent of total calories from proteins)
   - Age and food needs
   - Work and food needs
   - Climate or season and food needs
5. A balanced diet (proportion)
   - Importance of enough proteins etc.
   - Disadvantage of excess proteins
   - Sources of malnutrition
     - Insufficient food
     - Deficiency of particular constituents
       - Protein; vitamin; minerals; energy
6. Food fads
   - Related to ignorance, which is not aware of the facts about protoplasm and its nutrition
   - Related to simple-mindedness, which tries to solve a very complex problem with a very simple rule

QUESTIONS

1. Why can we not have a standard ration suitable for all the people of a country?

2. Why can we not have a standard ration for ourselves and eat the same thing every day?

3. How can the art of cooking help make people healthier? happier?

4. How can people spending plenty of money for food suffer from malnutrition?

5. What are the advantages of a mixed diet? disadvantages?

6. What kinds of food are best for the brain? for the heart? to make the hair grow?

7. What differences in diet should you prescribe for a minister and a blacksmith? Why?

8. What should you recommend for a person who is under weight? over weight?

REFERENCE READINGS

Farmers' Bulletin 142, Principles of Nutrition and Nutritive Value of Foods.

Farmers' Bulletin 975, Food Values; how Foods meet Body Needs.

Farmers' Bulletin 1383, Food Values and Body Needs shown Graphically.

Farmers' Bulletin 1313, Good Proportions in the Diet.

Farmers' Bulletin 817, How to select Cereal Foods.

Farmers' Bulletin 824, How to select Protein Foods.

Farmers' Bulletin 256, Preparation of Vegetables for the Table.

Farmers' Bulletin 717, Food for Young Children (from Three to Six Years).

WINCHELL, FLORENCE E. Food Facts for Every Day. Various chapters for special reports.

United States Bureau of Education. Keep-Well Series, No. 11. Malnutrition, Helpful Advice to Parents.

Get from the Superintendent of Documents, Government Printing Office, Washington, D.C., Prist List 11, Foods and Cooking.

CHAPTER XIV

HYGIENE OF FOOD AND FEEDING

Questions. 1. How often should a person eat? 2. What is the ideal number of meals per day? 3. What is the advantage of cooked food over raw food? 4. What is the harm of eating between meals? 5. What is the objection to drinking water with meals? 6. Why can we not eat concentrated food, like pure sugar, pure fat, and so on?

128. When to eat. A young infant eats but a little at a time, the food is liquid and quickly digested and absorbed, and the child is soon hungry again. Some people have relatively small stomachs, which cannot hold much food; they may have to eat at shorter intervals than others. Some people can get all they need for one day in two meals, without any discomfort, and many men and women have been quite healthy and happy with but a single meal a day.

In trying to find out the best rations for human beings, some experimenters discovered that they were in better working condition with only two meals a day than they were with three meals. The improvement may have been owing to the reduction in the total amount of food taken, or it may have been owing to the longer rest periods given the stomach. It is impossible to lay down fixed rules as to the number and regularity of meals, to suit all people and all conditions. On the other hand, it is just as unwise to avoid all regularity and eat whenever you happen to be hungry.

129. Cooking of food. The cooking of food has several distinct uses:

1. Cooking breaks up and softens the cell membranes of the plant and animal tissues used as food. This liberates the fats, proteins, and carbohydrates contained in the cells.

2. The heat makes the food more "tasty," adding to the pleasure of eating and causing the digestive juices to flow more freely in the mouth and stomach.

3. The action of the heat, with or without moisture, breaks up the starch grains, making them more easily digested.

4. The heat destroys bacteria and other microbes that may be present in the raw food. This reduces the danger of transmitting an infectious disease (see page 356). Cooked food is also more easily preserved against decay for the same reason.

Valuable mineral matters are sometimes lost when the water in which food is boiled is thrown away. Prolonged heating of food, especially in the presence of air or of alkalis, may destroy some of the vitamins. Still, all parts of value can be preserved by skillful cooking.

130. How to eat. To some people, eating is one of the chief pleasures in life. To others, eating is a duty: if not exactly disagreeable, it is still not altogether a pleasure. It is a mistake to let ourselves get into either class if we can help it.

1. *Emotions.* We want to get the most out of eating, even from an organic point of view. Anger, fear, worry, and anxiety almost always interfere with the proper secretion of digestive juices and with the operation of the muscles of the stomach and the intestine. When you are greatly excited or distressed, you are apt to say, "I cannot eat now"; and it is just as well to omit the meal until your feelings are more composed. There is less danger of starvation than there is of indigestion. On the other hand, whatever arouses pleasant feelings, whatever puts us into good humor, helps to tone up the digestive organs. It is therefore a wise custom to avoid unpleasant affairs before a meal. Pleasant conversation and good cheer are more helpful at mealtime than heated discussions or disputes. Even if the food itself means little to us, we can make the meal a happy event and so get the most out of it in every way.

2. *Relaxation.* Rapid eating makes impossible the complete stimulation of the taste and smell nerves, necessary to bring about secretion of the digestive juices. Rapid eating makes

impossible a thorough mixing of saliva with the food and the breaking up of food particles so that the gastric (stomach) juices may reach the proteins properly. The time saved by eating too rapidly is generally paid for later by indigestion.

3. *Water with meals.* Many people have the notion that water must not be taken with meals or with fish or with some other particular kind of food. Experiments show, however, that a person can take a quart of water at a meal without any harmful results but, rather, with beneficial results. Probably none of us ever drinks too much water. On the other hand, it is not well to take water or any other fluid while there is solid food in the mouth. Softening the food in this way hastens the swallowing and prevents a thorough mixing of saliva with the food. *Water should never be a substitute for saliva to soften the food or to aid in swallowing.* Then the water should not be too cold. Ice water as an introduction to a meal should especially be avoided, since chilling the stomach is a decided handicap for the work that is about to be placed upon it.

4. *Humanly speaking.* Cattle and guinea pigs can be kept alive indefinitely on a monotonous diet of "essentials." When the same thing is tried with human beings, they gradually lose those characters that distinguish them from the cattle or the guinea pigs; one of the things that drive men to drink and to drugs is the attempt to make them live like cattle. The cheapest diet is commonly recommended to people who have little of the pleasures of life and little time or training for enjoying the more refined forms of pastime and recreation; but the comparatively simple pleasures of eating should not be denied to these people.

131. Constipation. The digested foods are absorbed for the most part by the villi of the small intestine (see section 115). The refuse remaining by the time the mass has passed into the large intestine is now subject to the decaying activities of bacteria, which are always present in the food tube. There are thus produced substances which are poisonous if absorbed into the blood and distributed to the living cells of the body. The poisoning of the body by waste substances absorbed from the large intestine is sometimes called *autointoxication*, or self-

poisoning. The most common symptoms of constipation (the clogging of the bowels with refuse) are the following:

1. Headaches, especially the kind of headache that seems to hammer at your temples when you bend over.
2. The "blues"—a feeling of general dissatisfaction and grouch when you know of nothing to give you cause for dissatisfaction.
3. Drowsiness, in spite of plenty of sleep within a few hours.
4. A certain "tired feeling" when you have hardly done enough work to account for the tiredness.
5. Indigestion and loss of appetite.
6. A coated or "furred" tongue.

There are many headache powders on the market, but they never cure people of their trouble. They generally depress the action of the heart so that the circulation is lowered, and you do not *feel the pain* caused by the disturbance of these bowel poisons. The poisons, however, are still there, and more are being produced, whether you have a headache or not. The thing to do is to *remove the cause of the trouble*, not *merely hide the damage* from yourself. In a case of acute constipation one may obtain temporary relief by the use of a physic or an enema, but these should never be used as a regular thing.

Our food should have enough bulk to leave a considerable amount of undigested material in the intestine. This bulk, obtained chiefly from coarse vegetables, such as cabbage, lettuce, and turnips, is sometimes called *roughage*, from the idea that this mass of coarse cellulose sweeps out the bowels. There should also be plenty of juicy fruit, fresh or stewed, for the laxative property of the salts and other substances.

Since the chief cause of constipation is neglect of the bowels, the only real cure is the establishing of regular habits of emptying them. Mothers often try to get infants into regular habits, but many of them neglect the children when they are a little older. If regular habits are not established early, they are likely never to be fixed at all. It is certain that hundreds of thousands of people in this country suffer from constipation, and that there is no drug or medicine that will cure the disorder.

132. The teeth and their care. One of the commonest causes of indigestion is found in decayed teeth. People with poor teeth get into the habit of swallowing the food without chewing it. Then they blame their stomachs or the cook for their miserable feeling or even for the poor work they do.

The structure of a human tooth is shown in Fig. 81. The enamel is a hard protective casing. Trouble with the teeth very frequently begins with the breaking of this enamel. The enamel can be cracked by sudden changes of temperature, or by grinding it against some hard substance, as when you try to crack a nut with your teeth. Picking the teeth with a needle or some other hard body is also likely to scratch the enamel and thus to open the way for further damage.

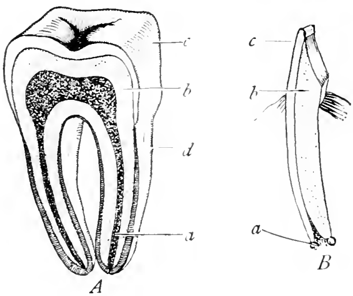


Fig. 81. Structure of mammalian teeth

A, human grinding tooth, showing central *pulp cavity* (*a*), containing nerves and blood vessels and surrounded by *dentine* (*b*). The crown is covered with *enamel* (*c*), and the root with cement (*d*). *B*, gnawing tooth of rabbit, which grows from below as fast as it wears away at the tip. The dentine wears away faster than the facing of hard enamel, thus keeping the chisel edge sharp

In the food that we eat there are many bacteria, of many kinds. In particles of food that cling to the teeth these bacteria begin their digestive activities (see Fig. 73). Some of the substances thus produced act upon the enamel, dissolving away this protective cover. Gradually a cavity becomes larger and deeper until it reaches the pulp and the nerve becomes exposed.[1]

[1] In recent years it has been found that many serious disorders in various parts of the body may result from a sick condition of the teeth. Studies on patients and experiments with animals have shown that when the root of a tooth is abscessed (infected with certain kinds of bacteria), living bacteria and the poisons which they produce can be carried by the blood to remote parts of the body and there set up local but serious disturbances such as rheumatism of the joints, inflammation of the heart, kidney disease, or ulcers of the stomach.

A thorough cleaning of the teeth at frequent intervals thus becomes necessary. The most reasonable time to clean the teeth is immediately after each meal. If you get the habit of doing this, it will postpone the rotting of the teeth a good many years. Unfortunately business hours are so arranged that most grown-ups cannot manage to look after their teeth after each meal. The best time for brushing the teeth, if it can be done but once a day, is just before retiring, that the bacteria may not continue their destructive activities during sleep.

The best cleaning material for the teeth—as for the skin or for clothes—is a good white soap. If you buy a dollar's worth of tooth paste or powder, you get several cents' worth of soap, together with some cheap perfume and a little powder added to scrub. The perfume does not help to keep the teeth clean, and it has been questioned whether the abrasive or scrubbing powder does not do more harm than good. If we begin with the younger children, we shall find that they can quickly learn to use plain soap on the toothbrush and do not need the fancy-smelling pink addition to make toothbrushing an agreeable habit.

In brushing the teeth the motion of the brush should be up and down, so as to reach all the spaces. If you brush crossways, the depressions along the edges of the teeth will not be reached at all. In setting out to fix a toothbrush habit, it is well to remember that the back teeth and the inner faces of the teeth need to be considered as well as the fronts of the front teeth.

133. Health habits. We have seen that we have no *direct control* over the workings of the digestive system. We must therefore establish habits at the few points where we have *indirect control.* The first point has to do with eating, and the establishment of suitable eating habits should be our first consideration. The second point at which we have control of the digestive system is in the establishment of habits related to the behavior of the large intestine. And, finally, there are certain general habits of exercise and breathing and sleeping which, on the one hand, are largely under our control and, on the other hand, have an influence on the digestive system:

1. The selection of food (see page 141).

2. The avoidance of food materials that are personally undesirable, however suitable they may be for others.

3. The avoidance of special sauces and spices as stimulants to the appetite.

4. The observance of fairly regular hours as to eating.

5. Leisurely attitude toward the meal. This would include the taking of a few minutes of rest before eating, when tired, as well as the avoidance of rushing off to work or to play after eating.

6. The establishment of a pleasant frame of mind for the meal, as well as other agreeable surroundings, whenever possible.

7. Thorough mastication of the food before swallowing. This does not mean counting the number of bites that you put into every mouthful; it means having the habit of chewing until the mass in the mouth is in a nearly fluid condition, so that it fairly "swallows itself."

8. Drinking plenty of water—before meals, between meals, as well as at meals, and before retiring—but never using it (or any other liquid) to "wash down" food in the mouth or to take the place of saliva for softening food.

9. Where outdoor work with the large muscles is not a part of the regular program, exercising (out of doors if possible) a certain amount every day.

10. Deep breathing, through the nose, not a few breaths now and then, but as a regular thing, all the time.

11. Plenty of sleep *every* night. This is better than sleeping a little most nights, in the hope of raising the average by sleeping later on Sundays or holidays.

12. Emptying the bowels every day, as nearly as possible at a fixed time.

QUESTIONS

1. What is the relation between pleasant feeling and the work of the digestive system?

2. What besides digestion is influenced by our emotions?

3. What are the advantages of jumping right into your work or play immediately after a meal? the disadvantages?

4. What are the advantages of softening the food with water or milk? the disadvantages?

5. What are some of the common causes of constipation? How can they be avoided?

6. What are some of the symptoms of constipation? How can they be overcome? What is the advantage of hiding symptoms?

7. What are some of the effects of constipation?

8. What is the difference between curing constipation and curing the symptoms? Which is preferable? Why?

9. What is the difference between curing constipation and preventing it? Which is preferable? Why? How would you do it?

10. In what different ways are the teeth related to health?

11. How can diseased teeth cause trouble in other parts of the body?

12. What is the best way to keep the teeth whole and sound?

REFERENCE READINGS

HOUGH and SEDGWICK. The Human Mechanism, chap. xix, The Hygiene of Feeding; pp. 398–402, 404–405.

WINCHELL, FLORENCE E. Food Facts for Every Day, chaps. vii and viii.

Farmers' Bulletin 1374. Care of Food in the Home.

United States Department of Agriculture. *Bulletin 637*, Method of Calculating Balanced Rations.

United States Bureau of Education. *Bulletin 37* (1921), Malnutrition and School Feeding.

Public Health Reprint 895, A Study of the Treatment and Prevention of Pellagra.

Public Health Reprint 707, Importance of Good Teeth and Prevention of Decay.

Public Health Reprint 622, Children's Teeth, a Community Responsibility.

American Medical Association. Nostrums and Quackery, "Food Tonics," p. 468; "Headache Cures," p. 494.

CHAPTER XV

THE AIR

Questions. 1. What has breathing to do with life? 2. How long can one go without breathing? 3. Are all parts of the air necessary for life? 4. Do all animals need the same amount of air? 5. How do fishes breathe? 6. Have whales lungs or do they breathe like fishes?

134. Air and life. The atmosphere has approximately the composition shown by the diagram in Fig. 82. When air is shut off, we suffocate, as in drowning. Now, what is the connection between air and being alive? This question has already

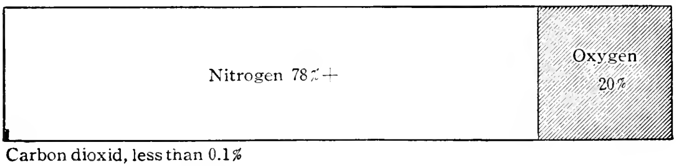


Fig. 82. Composition of the air

The air consists of several gases. The exact proportions of these gases are constantly changing. The most important of the gases are oxygen and carbon dioxid, but nitrogen is the most abundant

been answered in part (see section 76) by the statement that the energy of protoplasm, in all its activities, comes from the burning, or *oxidation, of materials derived from food.* The food is not burned directly, like the gasoline in an engine; it first undergoes many changes (digestion, assimilation) and becomes a part of the living protoplasm. Nor is the oxidation, or burning, like the familiar flame: it takes place only in the presence of water, whereas the fires with which we are familiar cannot be kept up under water. The nearest thing to the oxidation in protoplasm that is familiar is the rusting, or oxidizing, of iron,

which also takes place in water. Protoplasm oxidation probably depends upon the action of special *ferments*, or *enzyms* (see section 105). (1) It involves (*a*) material that can act as fuel, and (*b*) oxygen. (2) It results in the formation (*a*) of carbon dioxid (since all the fuel contains carbon), (*b*) of water (oxid of hydrogen, since all the fuel contains hydrogen), and (*c*) of other oxids, depending upon the character of the fuel.

The familiar fires give off heat and light. Oxidation in protoplasm may also result in other forms of energy. Some of these are motion (as in muscles), electricity, and the peculiar processes that are confined (so far as we know) to nerve and brain cells, such as thinking, wishing, suffering, enjoying.

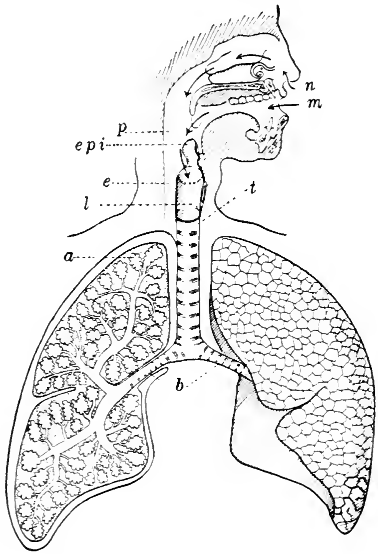


Fig. 83. The human lungs

The arrows show the course of air from the outside. *m*, mouth; *n*, nostrils; *p*, pharynx; *l*, larynx; *t*, trachea; *b*, bronchi. The right lung is shown cut open; the bronchi branch again and again, the last tubules ending in delicate expansions. *a*, the air cells, or sacs; *epi*, the epiglottis, which closes over the air pipe when food passes from the pharynx to the esophagus, *e*

135. Cell respiration. In an engine the oxidation takes place in the fire box or the cylinder. In a living plant or animal *oxidation takes place in every single cell*. In plants and animals that consist of very many cells the innermost cells are too far from the surface to get their oxygen directly from the surrounding air or water in this manner. In such cases the air either diffuses through special spaces (in plants) or special tubes (in insects; see Fig. 7), or it travels in a solution (blood) that reaches all parts of the body. In every case, then, the protoplasm of the individual cell (1) gets

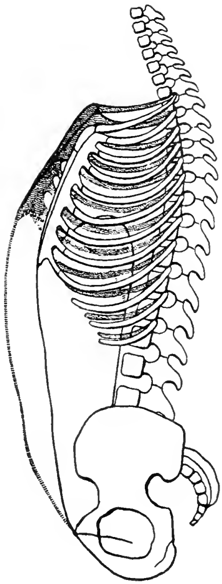


Fig. 84. The movements of breathing in man

When the muscular partition (called the *diaphragm*) between the chest cavity and the abdominal cavity is pulled down, the chest cavity is enlarged. When the ribs are raised, the chest cavity is also enlarged. The rib muscles and the diaphragm normally work in unison, alternately expanding and contracting the chest cavity. The shaded portion of the diagram shows the expanded condition — ribs raised and diaphragm lowered

its oxygen from its immediate neighborhood, and (2) discharges its carbon dioxid and other products of oxidation into its immediate surroundings.

136. Breathing in man. *Breathing*, or *respiration*, means a process of gas exchange—taking in oxygen and giving off carbon dioxid. It makes oxidation possible. In man (as, in fact, in all backboned animals except fishes and the young of amphibians) air is taken from the outside into the **lungs** (soft bags suspended in the thorax, or chest cavity), and carbon dioxid is discharged to the exterior from the same organs (see Fig. 83). The lungs consist of air sacs (which are lined with a layer of thin-walled cells and surrounded by very fine blood vessels) and air tubes (see Fig. 83). The filling of the air sacs with fresh air and the emptying of the lungs are brought about by the action of (1) muscles attached to the ribs and (2) a large muscular organ called the *diaphragm* (dī′a frăm). This separates the chest cavity from the abdominal cavity (Fig. 84). When the muscles of the ribs and of the diaphragm relax, the chest cavity shrinks; this forces the air out of the lungs. By contracting the muscles of the ribs and the diaphragm we force the chest cavity to enlarge, reducing the pressure in the lungs and drawing air into them. *Inspiration* and *expiration*, the two movements of air in *respiration*, are thus brought about by the alternate expansion and contraction of the thoracic cavity. There are sev-

eral steps between the outside air and the living cells; these are pointed out in the diagram (Fig. 85).

137. Control of breathing. When you wish to do so, you may hold your breath for a minute or two, or modify the rate and manner of breathing in other ways. Nevertheless our everyday breathing is an unconscious and involuntary process. The *way* you breathe is a matter of habit; the best control comes from establishing sound habits.[1] We need to practice correct breathing constantly rather than take special exercises to make up for bad habits. There are three points in regard to which faulty breathing habits are very common.

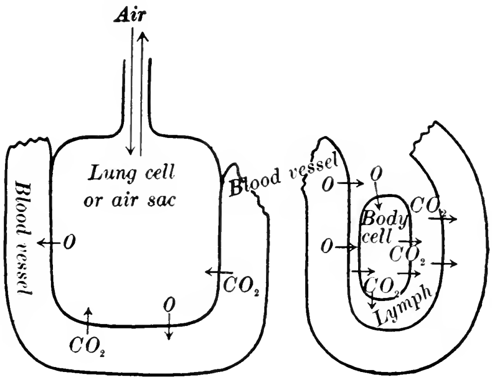


Fig. 85. External and internal respiration

The *external* respiration of the body consists of (1) the muscular movements of the ribs and the diaphragm; (2) the air movements into and out of the lungs; and (3) the osmotic movements of the gases into and out of the blood, through the linings of the air sacs. The *internal* respiration of the body cells consists of the exchange of gases between the cells and the blood or lymph

1. *Mouth breathing.* For several reasons we should acquire the habit of breathing through the nose rather than through the mouth (see Fig. 86).

a. By means of the slimy mucus secreted by the lining of the nostrils and by means of the hairs in the front part of the nostrils the dust particles are filtered out of the air we breathe.

[1] The rate of breathing is controlled automatically from certain nerve centers, which are influenced by the *proportion of carbon dioxid in the blood.* When you run fast, or exert yourself in some other way, the gas exchange in the lungs (and so the gas exchange in the blood and in the working cells) is increased; when you lie still, the gas exchange is reduced.

b. The long, narrow nose passages warm the air before it reaches the more delicate lining of the air pipes of the lungs.

c. The appearance of a mouth breather is unattractive.

d. Mouth breathing leads to snoring, which is due to the vibration of the soft palate by a current of air coming from the pharynx through the nose.

Fig. 86. Expression of face associated with adenoids

The open mouth, the sleepy eyes, the strain about the nose, are results of defective breathing due to obstructions in the rear air passages of the nose. (From a photograph by Jessie Tarbox Beals)

People do not snore while awake; during sleep the muscles of the mouth and the palate relax, and the moving air sets up a vibration of the hind palate. A frequent cause of mouth breathing is some obstruction in the nasal passage. The most common obstruction is an outgrowth of the lining in the hind nostrils, called an *adenoid* growth (see Fig. 87). Such a growth is a handicap to a child, since it interferes with proper breathing and sometimes with the circulation of blood in the head.

2. *Deep breathing*. Some of the air sacs of the lungs (especially those in the upper corners) can be ventilated only by forced breathing; and it is in these very parts that tuberculosis of the lungs most frequently begins. It is desirable that all the air sacs be completely filled from time to time. Vigorous exercise of the large muscles of the arms and legs and trunk will automatically force deeper breathing. Those of us whose occupa-

tions do not regularly compel deep breathing should make outdoor games a part of our program. Outdoor playing is certainly better than special exercises in breathing, and a healthy program of play and work will give a lung capacity proportioned to our needs.

3. *Posture.* It is impossible for the air to reach all the corners of the lungs if the shoulders are curved over or forward. The shoulders must be kept back to give the chest a chance to expand freely. However, good posture is not merely a matter of correct form; it is closely related to a person's spirit or attitudes (see Fig. 143). It is probably true that in most cases a boy or girl who stands up to the world joyfully and courageously will automatically (1) maintain correct posture, (2) breathe correctly, and (3) use the voice correctly. In many cases, however, we get into bad habits early in life, and these have to be corrected. Moreover, in many cases the lack of joy or of courage probably results from defective posture brought about by neglect during the early years. At any rate, breathing and many of the other important bodily functions are closely related to the individual's state of mind, and all have to be right together.

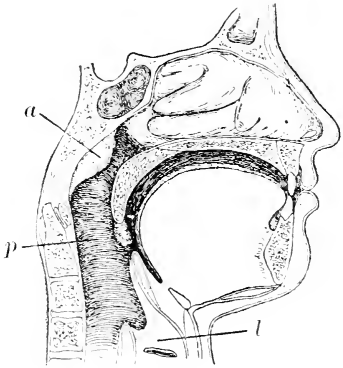


Fig. 87. Adenoid growths

In the passage between the nostrils and the pharynx, *p*, shapeless masses of tissue, *a*, sometimes grow out, obstructing the movement of air from the nose and leading to mouth breathing. When adenoid growths are present they should be removed by a physician. The operation is simple and safe. *l* is the larynx, or voice box

138. Clothing. Clothing that cramps the ribs or the waist restrains proper breathing. Tight corsets and belts do not cause one to suffocate, but they do prevent one from breathing deeply, using the diaphragm as well as the rib muscles. Tight lacing is likely also to have an injurious effect upon the liver, the stomach, and the intestines.

THE AIR

1. Composition of the atmosphere
   - Nitrogen, 78 + %; oxygen, 20 %; carbon dioxid, 0.1 − %
2. Relation of air to life
   - Oxidation of protoplasm
     - Yields energy
       - Heat
       - Motion
       - Chemical action
       - Electricity
       - Light
       - Nerve and mental energy
     - Products of oxidation
       - Carbon dioxid (CO_2)
       - Water
       - Urea
       - (Other oxids)
   - Comparison with other oxidation
3. Respiration
   - In one-celled organisms
     - Income
     - Outgo
   - In many-celled organisms
     - Income
       - Special openings
       - Special tubes
     - Distribution
       - Blood and lymph
       - (Tracheæ in insects)
     - Gathering of oxids
     - Outgo
4. Human breathing system
   - Structure
     - Lungs
     - Connections with outside
     - Connections with body cells
   - Process of breathing
     - Action of diaphragm
     - Action of rib muscles
     - Effects upon air currents
5. Breathing habits and control
   - Mouth breathing versus nose breathing
     - Removal of dust etc.
     - Temperature
     - Disagreeable appearance
     - Disagreeable sounds
   - Adenoids
     - What they are
     - How they influence breathing
   - Deep breathing
   - Posture
     - Related to breathing
     - Related to attitude
   - Exercise
   - Clothing

QUESTIONS

1. How can we show that air is necessary to keep a fire going?

2. How can we show that a fire gives off water and carbon dioxid?

3. How can we show that the lungs give off water and carbon dioxid?

4. Why should you expect a pound of insect protoplasm to use up more oxygen in an hour than a pound of earthworm protoplasm?

5. Why is it difficult for a person to do his usual amount of work on a very high mountain?

6. How should you expect a decrease in the atmospheric nitrogen to influence living things?

7. How does the gas exchange in a one-celled animal (the ameba, for example) resemble the gas exchange in a one-celled plant (green slime, for example)? How does gas exchange differ in the two organisms?

8. How does gas exchange in a one-celled animal resemble breathing in man? How do the two differ?

9. How does breathing in man resemble breathing in an insect? How do they differ?

10. How can you show that posture is connected with a person's mental state? What use is sometimes made of this fact?

REFERENCE READINGS

HOUGH and SEDGWICK. The Human Mechanism, chap. x, Respiration.
FISHER and FISK. How to Live, pp. 18–28.
COCKERELL, T. D. A. Zoölogy, chap. v, Respiration.

CHAPTER XVI

HYGIENE OF RESPIRATION AND VENTILATION

Questions. 1. Why is outdoor air better than indoor air? **2.** Why does dry air feel colder than moist air? **3.** What is the harm in breathing through the mouth? **4.** Is it bad to run until you are out of breath? **5.** Why are drafts dangerous?

139. Ventilation and its problems. Every breath we take removes from the air a certain amount of oxygen and replaces it with carbon dioxid. In order to keep up the working power the body must be supplied with enough air to furnish the needed oxygen and to carry away the excreted carbon dioxid. Of course it is not necessary to change all the air in a room for every breath. It is safe to use air in which the amount of carbon dioxid has been increased from about three or four parts in 10,000 (what it is in ordinary outdoor air) to 6 parts in 10,000, or even much more (see Fig. 88). How much fresh air should be supplied for each person in a school or factory? Recent experiments show that under ordinary conditions the air contains neither a "breath poison" nor a dangerous amount of carbon dioxid, even when the ventilation is decidedly bad. Nor is there danger that the proportion of oxygen will fall below a safe limit. The chief problems of ventilation are (1) to keep the air at a suitable temperature, (2) to regulate the moisture and dust in the air, and (3) to keep the air in motion.

1. *Temperature.* The temperature of the air in a living room, schoolroom, or workshop should be kept as nearly as possible at 65° F. At this temperature the internal temperature of the body or blood remains fairly constant (at about $98\frac{1}{2}$° F.) through the steady radiation of heat from the surface and through the evaporation of water. As the temperature rises we remain comfortable by increasing sweat or perspiration and

evaporating more water from the skin. At 70° it begins to be uncomfortable and to affect the efficiency of our work.

2. *Moisture.* The more moisture there is in the air, the slower the evaporation will be, and the more heat the body will retain. The lower the humidity, the more rapidly will water evaporate, and the more rapidly will the body lose heat. A hot, stuffy room interferes with breathing and comfort because it interferes with the *radiation of heat and evaporation of water in the lungs.*

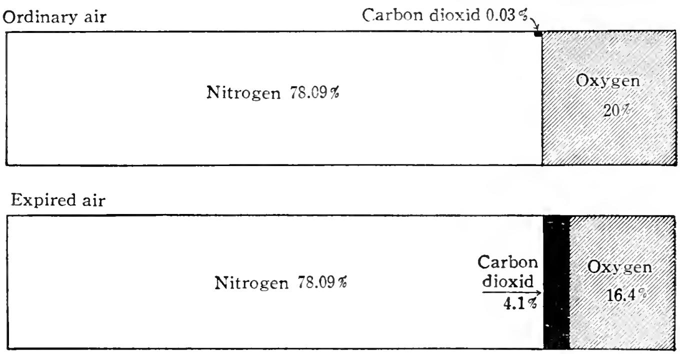


Fig. 88. Effect of breathing on the air

The ratio of oxygen to carbon dioxid is changed from 700:1 to 4:1

The advantage of large spaces in workshops and other places where people are likely to be crowded together is that they make it possible for the heat and moisture given off by the body to be removed fast enough to insure comfort. The amount of oxygen or of carbon dioxid seems to have nothing to do with the difficulties of suitable ventilation.

The drowsy effects of a badly ventilated room are due to the congestion, or crowding, of the skin capillaries with blood and the corresponding lack of blood in the brain and the muscles. In the Black Hole of Calcutta, in which so many people lost their lives, the victims were supposed to have died from lack of oxygen. It seems more likely that in such cases death really results from heat stroke, due to the excessive humidity (from the perspiration and lung transpiration of the people) and the high temperature (from the heat radiated by the bodies).

In artificially heated houses there is often danger of having the air too dry, since the air coming from the outside contains but a fraction of the moisture which it may hold after it becomes warmed. Special efforts must be made to insure enough moisture.

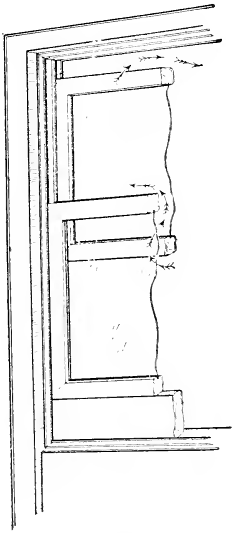


Fig. 89. Window ventilation in cold weather

So long as weather permits, ventilation should be by means of windows, open at top and bottom for the freest possible circulation of air. In cold weather a window board placed under the lower sash prevents drafts and allows circulation between the sashes and the top

3. *Movement*. The air next to the skin soon becomes saturated with moisture and nearly as warm as the body itself. If this air is allowed to remain next to the skin undisturbed, we soon become very uncomfortable. Where there are large rooms and windows, and not too many occupants in a room, the natural movement of the air will be sufficient (see Fig. 89). When many people have to be in a room, as in schools and workshops (especially in winter, when artificial heating is necessary and windows are likely to be closed), there is need of special attention to ventilation, and forced ventilation may become necessary. It is often found desirable to use an electric fan to insure movement of the air, even when there is no change in the amount or quality of the air.

Many people fear drafts as though the mere movement of the air were dangerous. What is dangerous about a draft is the sudden chilling of the skin, with a resulting congestion of the blood vessels. In general, chilling the body lowers the resistance to infection (see page 339). By means of cold baths most of us can accustom the skin to react vigorously to rapid changes in temperature.

140. Suffocation and drowning. When the gas exchange in the air sacs of the lungs is stopped for several minutes, suffocation takes place, and death may result. Suffocation may be due

to the replacement of air by some other gas, or it may be due to the exclusion of air. The replacement of the air in the lungs by water is called *drowning*. Breathing may also be stopped by a severe electric shock, which acts on a group of nerves that control the breathing movements. Suffocation and drowning are commonly fatal, but in many cases life may be saved by prompt

Fig. 90. Silvester method of artificial respiration—expanding the chest

After drawing out the tongue and placing the patient on the back with a block or roll under the shoulders, to keep the chest raised and the head thrown back, kneel behind the head and grasp the arms just below the elbows. Draw the arms slowly backward over the head, and hold them there about one second

and persistent action. It is necessary (1) to empty the lungs of the water or foreign gas and (2) to reëstablish the breathing movements.

When a person has been drowned, the first thing to do is to place the body, face down, in a position that will cause the water to flow out of the lungs. A child may be lifted by the feet. Breathing movements should be begun at once.

In the Schaefer method of artificial respiration the patient is laid face down, with the arms stretched forward beyond the head. The head is turned to one side and supported on a cloth. The operator kneels, straddling the subject's thighs and facing his head, and places the thumbs over the small of the back and the fingers over the lowest ribs. Then, by swinging forward and

Fig. 91. Silvester method of artificial respiration—contracting the chest

After the arms have been held above the head about one second, push the elbows slowly forward and downward until they are in the position shown. Press the elbows firmly against the chest and hold them there about one second, to drive all the air out of the lungs. (Photographs and instructions, Figs. 90 and 91, from the United States Bureau of Mines)

back, he alternately compresses and releases the chest at the rate of from twelve to fifteen times a minute. The movements should be kept up until natural breathing begins, but should not be given up in less than an hour. The patient's tongue should be pulled out and kept out, to prevent it from slipping back into the throat and obstructing the windpipe.

The Silvester method of artificial respiration is shown in Figs. 90 and 91.

In case of *asphyxiation*, or suffocation by gases or by electric shock, the same procedure should be followed, except that it is not necessary to take special steps for emptying the lungs.

Under the supervision of the United States Bureau of Mines squads of miners are instructed in the resuscitation, or reviving, of people who become asphyxiated by gases or by electric shock. This bureau conducted a series of experiments to determine which of the mechanical resuscitating devices was best for various purposes. It was found that more reliance could be placed on quick action by men who understood how to establish respiration than on most of the machines. *It is always safer to begin work by hand than to wait for the best machine.*

From experiments conducted on various animals we now know that our breathing is influenced by the amount of carbon dioxid in the blood. When you run for a while the muscle cells work harder and oxidize more sugar and use up more oxygen and give off more carbon dioxid. The excessive carbon dioxid in the blood acts upon certain nerves, which forces deeper breathing. That is why we breathe faster when we exert ourselves. A very useful application of these facts has recently been made. When a person is overcome by gases or fumes, air with a certain amount of pure carbon dioxid is forced into the lungs. This gas, acting in the same way as carbon dioxid that results from overexertion, forces deep breathing and so helps to restore normal breathing again. By this method firemen who had been suffocated at a fire were quickly restored so that they were able to go on with their work immediately.

141. Poisonous fumes. With the increasing use of internal-combustion engines, and especially of automobiles, there has come a serious danger of poisoning by carbon monoxid (CO). Like carbon dioxid (CO_2), this gas combines with the red pigment of the blood corpuscles; but, unlike carbon dioxid, it brings about chemical changes that are not reversed when oxygen is present. Every year many persons die as a result of

inhaling fumes in a closed or poorly ventilated garage, since this gas is produced when a motor is driven with insufficient air.

142. Summary on breathing and ventilation. It is only in recent times that we have found out the close connection there is between our breathing habits and conditions and our health, happiness, and efficiency. The most important details that have been discovered are the following:

1. Outdoor air is better than indoor air in every way.
   a. It is better for playing, even in the cold and rain; suitable clothing will make up for these.
   b. It is better for work, since a person can accomplish more in a given time when breathing outdoor than when breathing indoor air.
   c. It is better for health, even to sleep out of doors.
2. Nose breathing is in every way better than mouth breathing.
   a. Where mouth breathing is due to adenoids, these growths should be removed.
   b. Where mouth breathing is due to bad habits, these habits should be corrected.
3. Deep breathing is better than shallow breathing.
   a. Where shallow breathing is due to improper clothing, the clothing should be changed.
   b. Where shallow breathing is due to habit, correct habits should be acquired through outdoor games, outdoor work, etc.
4. Ventilation is necessary not only to keep down the proportion of CO_2 and to keep up the proportion of ogygen in the air, but also to (*a*) regulate the moisture, (*b*) regulate the temperature, (*c*) keep the air moving, (*d*) remove disagreeable odors, (*e*) remove gases and fumes, (*f*) remove dust.
5. A person suffocated or drowned is not to be given up for dead before every possible effort to resuscitate him has been made in vain.
6. Dust as a source of danger to the health of the body and to the lungs in particular is discussed more fully in Chapter XXXVI.
   a. Mechanical dust, soot, and smoke (including tobacco smoke) coat the lining of the air sacs and reduce the breathing surface.
   b. Hard dust may scratch the lining of the air sacs and thus increase exposure to infection.
   c. Dust carrying microbes is a direct source of danger.
   d. Chemical dust and fumes may poison the blood.

QUESTIONS

1. How many cubic feet of air is there for each person in your schoolroom? in the living room or dining room at home?

2. Why is a kitchen at 70° F. likely to be more uncomfortable than a sitting room at the same temperature?

3. How does stirring up the air add to the comfort?

4. How does fanning help to keep cool?

5. What are the disadvantages of stirring up the air?

6. What is the difference between suffocation and drowning? What difference should there be in the treatment?

7. What is the difference between suffocating by carbon dioxid and suffocating by carbon monoxid?

8. Why should the Bureau of Mines be concerned with resuscitation?

9. What other public agencies are concerned with reviving drowned or suffocated persons?

10. What public agencies are concerned with keeping air properly ventilated in public places?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, chap. xxix, Ventilation; pp. 397–398, 402–404, 405–406.
Fisher and Fisk. How to Live, pp. 7–14.
Public Health Reprint 753, Adenoids.
Public Health Reprint 854, Effects of High Temperatures and Humidities on Body Temperature and Pulse Rate.
Supplement 2, Public Health Reports. Indoor Tropics.
Public Health Reprint 728. Treatment of Carbon-Monoxid Poisoning.
United States Bureau of Mines. Technical Paper 82, Oxygen Mine Rescue Apparatus and Effects on Users.

CHAPTER XVII

DISTRIBUTION OF MATERIAL WITHIN THE BODY

Questions. **1.** Do all animals have blood? **2.** Do all animals have hearts? **3.** Is the sap of plants the same as the blood of animals? **4.** How does blood help keep us alive? **5.** How can the blood of one person be made to work in the body of another (transfusion)? **6.** Can the blood of one animal be transfused into the body of another? **7.** Why does the blood of some people clot more quickly than that of others?

143. Transfer of materials in plants. All plants and animals except the very smallest have some way of distributing materials between the surface and the inside cells, or between the different parts of the body. In most of the familiar plants one set of tubes or vessels carries water and dissolved salts from the roots, through the stems, to the leaves, and another set of vessels carries organic food from the leaves to other parts of the plant, where it is either used up in the growth of new organs or stored up, as in seeds or potato tubers. The two currents are independent of each other, consisting of different materials and being without connections at any point (see section 97).

144. Blood. In most of the familiar animals the **blood** *moves in a continuous stream.* In the clams the blood contains a bluish substance, called *hemocyanin,* which easily combines with oxygen and thus carries oxygen obtained from the surrounding water by diffusion into the blood vessels of the skin and *gills.* In the *earthworm* the blood carries in solution a reddish substance, **hemoglobin**, which behaves in the same way as hemocyanin. Among the backboned animals the blood has a more complex structure and flows in an elaborate system of vessels, driven by a pumping organ, the *heart.* Human blood consists of a colorless fluid, called *plasma,* and a number of small bodies, the corpuscles, floating in it (see Fig. 92).

145. The plasma. The plasma consists chiefly of water. In it are dissolved various salts, organic substances derived from the digested food, a little oxygen and carbon dioxid, and substances derived from various organs and tissues, some of them waste products. Not every drop contains all these materials, or all of them in the same proportion, for substances are constantly coming into the blood and other substances are passing out.

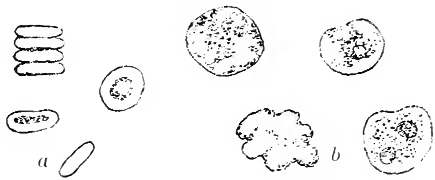


Fig. 92. Human blood corpuscles

a, the more numerous *red* corpuscles (about $\frac{1}{3200}$ of an inch in diameter) in flat and in edge view; *b*, the less numerous white or *colorless* corpuscles, or *leucocytes* (some barely larger than the red ones, others many times as large) in resting and in moving stage; note granulations and nuclei

While passing through certain organs the blood takes up, in addition to wastes, special chemical products that have peculiar effects upon the organs and activities of the body. For example, from the **thyroid gland**, a Y-shaped, spongy body lying in front of the larynx, the blood absorbs a substance that has an important influence upon the development and workings of the brain. From the pancreas the blood absorbs a substance that has an important influence upon the oxidation of sugars in the cells. In recent times it has been possible to prepare extracts of this substance (insulin) from the pancreas of other animals and to use it in overcoming the condition known as diabetes, in which sugars are insufficiently oxidized.

From little bodies that lie next to the kidneys the blood absorbs two or more substances that influence the muscles of the blood vessels and that have some effect upon the nervous system. The amount of these materials is increased whenever strong feelings are aroused, as fear or anger; and an increase of the amount in the blood causes the liver to put out more glycogen, which becomes available as fuel in the active organs. This seems to be the reason why a person can put out more energy when excited. The *adrenin*, as this substance is called, also interferes with the secretions and contractions of the stomach, so that digestion cannot go on happily during anger (see page 153), and it hastens the clotting of blood (see section 148). The products of a soft organ lying in the front part of the chest in young mammals, the *thymus*, are

distributed by the blood and have an important influence upon the growth of the animal. Another of these substances that affects growth is absorbed by the blood from a little body lying at the base of the brain, the *pituitary*.

These various substances, or ferments, are sometimes called **internal secretions**, because they are absorbed by the blood directly from the tissues of these special organs, instead of coming out through ducts, or tubes, as is the case with the more familiar glands. These internal secretions are also called **hormones**.

146. The red corpuscles. These cells are found in all vertebrates. They contain *hemoglobin*, which combines chemically with either oxygen or carbon dioxid, according to which is more abundant. This makes the red corpuscle a gas carrier floating in the plasma (see Fig. 85).

Red corpuscles, like the white ones, are really unattached cells. They originate by cell division of special cells in the marrow of bones. At first they have a nucleus, but this soon disappears.[1] The older corpuscles go to pieces, and their hemoglobin is taken up by the liver and converted into part of the *bile* (see section 113).

147. The white corpuscles. We owe much of our understanding of the white corpuscles to the great Russian biologist, Élie Metchnikoff, who was director of the Pasteur Institute in Paris. Like *Ameba* (see page 59), these cells consist of naked protoplasm and have no fixed shape. Whereas the one cell of the ameba carries on *all* the functions of a living body, the various cells of a many-celled animal like an ant or a baby have *specialized* functions as well as specialized structures. Now the white corpuscles are in many ways the least *specialized* cells in the body. They have the *general* qualities of protoplasm in the greatest degree.

1. As eating cells (or **phagocytes**, which means "eating cells," as they were called by Metchnikoff) they are capable of flowing about or engulfing foreign particles with which they may come in contact. They may swallow and digest dead particles

[1] Among vertebrates other than mammals the corpuscle retains its nucleus.

resulting from the breaking down of tissue cells, as well as live cells that get into the blood from without, such as bacteria of various kinds.

2. As sensitive or irritable cells they may respond to a chemical stimulation, such as the presence of various kinds of poisons, by producing substances capable of counteracting or neutralizing foreign chemicals.

3. As moving cells they wander about from the lymph to the blood, or vice versa, and even into the intestines. In this way they carry with them dead matter to be thrown out, or they crowd together in large numbers and produce special substances that counteract a local chemical disturbance.

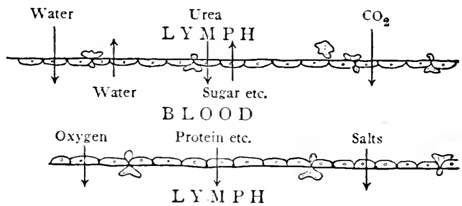


Fig. 93. What goes through the wall of a capillary

From the blood within the capillary, water, salts, food, and oxygen pass out by osmosis; from the surrounding lymph, carbon dioxid, urea, and water pass into the blood. White corpuscles work their way through the wall of the capillary, between the cells

Because of their peculiar behavior in the presence of foreign substances and particles we have come to think of the white corpuscles as the most important agents of keeping the body in health, at least in relation to certain special diseases.

White corpuscles are found in all animals that have blood, and they are very much alike in all, so far as general appearance and behavior are concerned. In our bodies the white corpuscles probably originate by the division of ameba-like cells in the bone marrow and in certain enlarged lymph spaces containing crowds of the white corpuscles.

148. Clotting of blood. When blood is removed from a blood vessel, whether it is taken out of the body or not, it usually becomes clotted, or thickened. This clotting is brought about by the coagulation, or solidifying, of a certain protein in the plasma known as *fibrinogen,* which means "fibrin-maker," since the

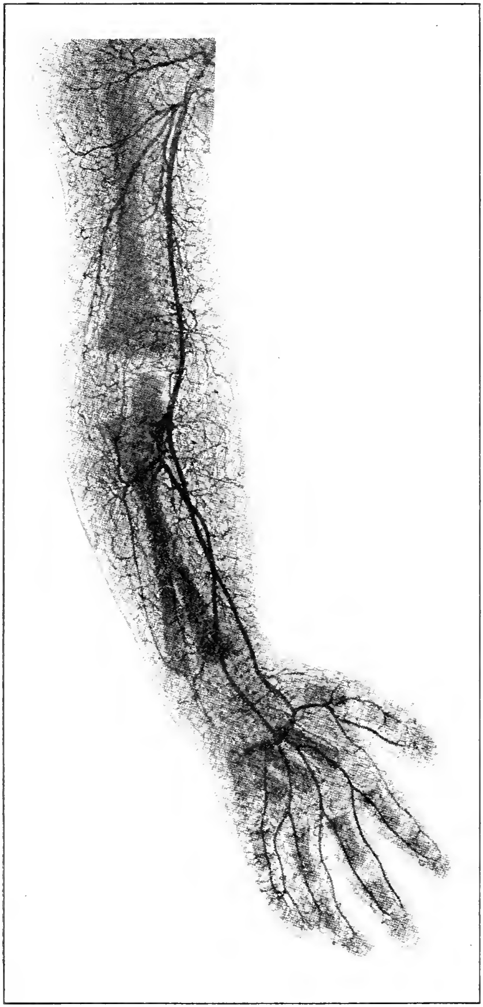


Fig. 94. An X-ray view of arteries of the arm

The arteries of a new-born baby (dead) were injected with a mixture that is opaque to the X-rays, originated by Dr. Eben C. Hill. The blood vessels reach all parts of the organ. (Courtesy of Johns Hopkins *Bulletin*)

solidifying is in the form of fine fibers. The ferment that causes the coagulation becomes active when the lining of a blood vessel is injured; possibly it is formed only at such times. At the mouth of a small cut this clot soon stops the bleeding, and it furnishes a protective covering until the wound is healed.

149. Serum. If blood is allowed to stand for a time in a glass vessel, we can see the mass of fibers detach themselves from the walls of the vessel until the clot floats at last in a clear liquid which is almost colorless or slightly yellowish. This clear liquid is called **serum** and is practically the same as blood plasma but lacking the protein fibrinogen. What-

ever is characteristic or distinctive of the plasma of an individual or of a species will be found in the serum.

150. The lymph. The blood is confined to a set of tubes from which it cannot escape—as blood. The whole system is therefore called a *closed* system. Outside the blood vessels, filling definite tracts as well as spaces between tissue masses and cells, is a colorless liquid called the **lymph**. It is *from the lymph* that the cells obtain their food supplies, water, salts, ferments, and oxygen; and it is *to the lymph* that they discharge their carbon dioxid, urea and other wastes, and any special substances that they may secrete. There is a definite connection between lymph spaces and certain large blood vessels. The main communication between the lymph and the blood is by osmosis through the smallest blood vessels (see Fig. 93). The lymph, like plasma or serum, consists chiefly of water, and carries practically the same kinds of substances in solution. In addition the lymph has many white corpuscles floating in it, so that it may be considered the same as blood but lacking red corpuscles.

151. The heart and the vessels. The blood is kept moving by the rhythmic contractions of the pumping organ, the **heart**. Blood comes *into* the heart through vessels which are called **veins**; blood flows *out of* the heart in tubes known as **arteries**. The arteries branch and divide again and again, reaching all parts of the body. The smallest branches, the **capillaries**, form a network, combining into larger and larger tubes and bringing the blood over from the arteries to the veins.

Among warm-blooded animals (birds and mammals) the heart is a double organ: blood cannot pass directly from the right half to the left half. Each half of the heart consists of an upper *receiving* chamber and a lower *pumping* chamber (see Fig. 95).

The *left heart* is somewhat larger and stronger than the right heart. Its **ventricle**, or pumping chamber, closes up, or contracts, at fairly regular intervals, forcing the contained blood into the largest artery of the body, the *aorta*. The branches of the aorta carry the blood on to the various organs and tissues. The **auricle**, or receiving chamber, of the left heart is connected

with a large vein that brings blood gathered from the capillaries of the lungs. The opening between the receiving chamber and the pumping chamber is guarded by a set of valves that prevents the blood from flowing back when the ventricle contracts. Another set of valves prevents the blood from flowing back from the aorta into the ventricle when the latter expands again. *The left heart thus pumps blood received from the capillaries of the lungs into arteries all over the body.*

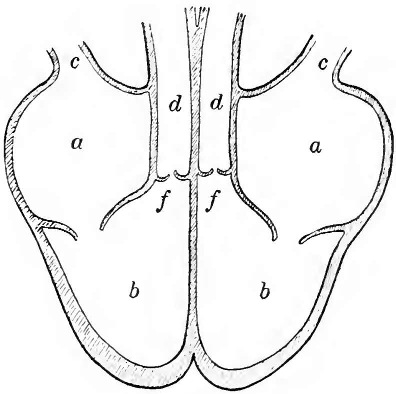


Fig. 95. Diagram of the human heart

aa, receiving chambers, or *auricles*; *bb*, pumping chambers, or *ventricles*; *cc*, main veins, bringing blood to the heart; *dd*, main arteries, carrying blood away from the heart; *ff*, valves, preventing back-flow from arteries to ventricles; between *a* and *b*, valves preventing back-flow from ventricles to auricles

The *right heart* receives blood into its auricle from two large veins, and passes it into the ventricle, or pumping chamber. The auricle and the ventricle on the right side are connected, as are the corresponding chambers on the left side, with a valve that prevents the back-flow of blood when the ventricle contracts. The right ventricle pumps blood into a large artery (*pulmonary artery*) that carries it to the capillaries of the lungs. *The right heart pumps blood received from all over the body to the capillaries of the lungs.*

152. The double circulation. The stream of blood makes two circuits: (1) from the heart (left) through arteries, capillaries, and veins of the body and back to the heart; (2) from the heart (right) through arteries, capillaries, and veins of the lungs and back to the heart (see Fig. 96). The blood-stream may be traced from any point and back to the start only by passing through the two sides of the heart, through the *pulmonary*, or lung, circuit, and through the *systemic*, or body, circuit. Thus,

beginning, for example, in the capillaries of the hand, the blood flows into the veins and is gathered into larger and larger vessels, reaching the right auricle. From this it goes to the right ventricle; and when the latter contracts, the blood is forced into the pulmonary artery. The lung arteries divide into smaller and smaller branches, the smallest being the capillaries that lie under the lining of the air sacs in the lungs. As the blood flows on, it is gathered into larger and larger veins that unite to form the pulmonary vein, which empties into the left auricle. From the left auricle the blood goes to the left ventricle, and from this it is pumped into the aorta. An artery branching from the main artery carries blood into the arm, and as the arteries divide, becoming smaller and smaller, we at last reach the capillaries in the hand, from which we started.

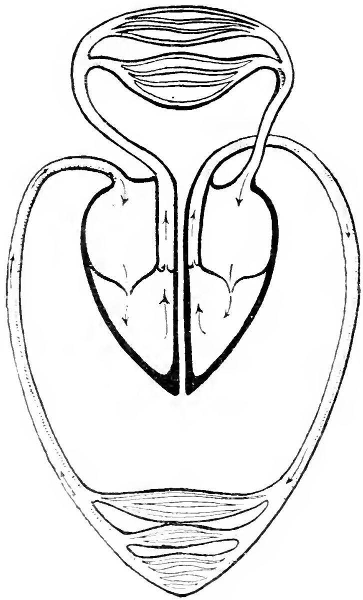


Fig. 96. The "double circulation" of the blood

The arrows indicate the direction of blood flow. The shaded portion represents blood lacking in oxygen. From the right heart (shaded) the blood passes to the lungs, from which it returns to the receiving chamber of the left heart with its carbon dioxid replaced by oxygen. From the pumping chamber of the left heart the blood passes to all parts of the system, or body, and returns to the receiving chamber of the right heart with its oxygen replaced by carbon dioxid

This "double circulation" makes possible a rapid exchange of carbon dioxid for oxygen. In the human body all the blood passes through the heart (and therefore through the capillaries of the lungs) once in from twenty-three to thirty seconds. The exchange of gases in the air sacs of the lungs has already been described (see Fig. 85).

153. Changes in the blood. While in the capillaries of the various tissues of the body the blood absorbs from the surrounding lymph (by osmosis) carbon dioxid, urea, and other substances that are present in relatively large proportions (that is, compared to their concentration in the blood plasma); and by the same process it loses food materials, salts, oxygen, and ferments that are relatively more abundant in the blood than in the surrounding liquids. In certain parts of the body additional changes take place in the composition of the blood. In the intestines, for example, much of the digested food is absorbed into the blood. In the kidneys much of the urea, salts, and other waste substances is taken from the blood.

DISTRIBUTION OF MATERIAL WITHIN THE BODY

1. Comparison of one-celled organisms with many-celled organisms regarding relation to environment
    - Income; outgo
2. Comparison of plants and animals regarding means of distributing material
    - The two kinds of sap in plants and the two kinds of vessels
    - The blood in animals
3. Composition of mammalian blood (including human blood)
    - Plasma
        - Water
        - Dissolved nutrients
        - Dissolved salts
        - Dissolved gases
        - Ferments (hormones)
        - Fibrinogen
    - Corpuscles
        - White
            - Eating cells (phagocytes)
            - Moving cells
            - Irritable cells
        - Red
            - Gas carriers (hemoglobin)
4. Clotting of blood
    - Fibrin formation
        - Conditions of clotting
            - Cut or bruise of capillaries
            - (Some diseased conditions)
        - How it takes place
        - Possible uses to organism
        - Remaining fluid (serum)
5. The lymph
    - Its character
    - Its composition
    - Its functions

6. The pumps and the pipe-lines of the blood system
   - Structure of the heart
     - Chambers
       - Receiving (auricles)
       - Expelling (ventricles)
     - Valves
       - Between chambers on same side
       - Between ventricles and outlets
   - Vessels
     - Out-carrying (arteries)
     - In-carrying (veins)
     - Crossover (capillaries)
7. The circulation
   - Systemic
     - Left ventricle
     - Aorta
     - Systemic arteries
     - Systemic capillaries
     - Systemic veins
     - Right auricle
   - Pulmonary
     - Right ventricle
     - Pulmonary arteries
     - Pulmonary capillaries
     - Pulmonary veins
     - Left auricle
8. Loading and unloading the blood-stream
   - At what points the blood takes on what it carries
   - At what points the blood throws off what it carries

Nutrients	Oxygen	Hormones
Water	Carbon dioxid	Urea
Salts		

QUESTIONS

1. How does the fibrovascular bundle of a plant show division of labor?

2. How are the various functions of our blood system carried on by a one-celled plant or animal?

3. What is the appearance of a red blood corpuscle under the microscope? of a white corpuscle?

4. How does the white corpuscle obtain its food and oxygen?

5. In what ways is the blood plasma like serum? In what ways is it different?

6. How does serum resemble lymph? How do the two differ?

7. What are the similarities between lymph and plasma? What are the differences?

8. What work is done by the upper chambers of the heart? by the lower?

9. What work is done by the right chambers of the heart? by the left?

10. What changes take place in the blood while it is passing through the capillaries of the intestines? of the lungs? of the muscles of the arm?

11. How does the blood in the pulmonary veins differ from the blood in veins leading from the brain?

12. How does the blood in the pulmonary arteries differ from the blood in the pulmonary veins? in muscular veins?

13. How does the blood in the arteries going to the brain differ from that in the veins leading from the brain?

14. How is the work of the heart carried on in a tree?

REFERENCE READINGS

Bergen and Caldwell. Practical Botany, pp. 78–80.
Osterhout, W. J. V. Experiments with Plants, pp. 224–258.
Bigelow, M. A. Applied Biology, pp. 53–55, 482–486.
Hough and Sedgwick. The Human Mechanism, pp. 135–151.
Parker, George H. Biology and Social Problems, lecture on Hormones.
Public Health Reprint 896, Importance of our Knowledge of Thyroid Physiology.

CHAPTER XVIII

HYGIENE OF THE BLOOD AND THE CIRCULATION

Questions. 1. How can nosebleed be stopped? 2. How should bleeding from a wound be stopped? 3. Why does the doctor feel the pulse? 4. Why does the doctor listen to the heart?

154. The health of the blood. The condition of the blood determines the life conditions, and so the health, of all the cells and tissues of the body. To keep the blood in suitable condition we must supply it with plenty of water, with suitable food in right quantities, with necessary salts, and with oxygen; and we must give the blood a chance to get rid of carbon dioxid and the other waste substances that it gathers from all parts of the body. This is but another way of saying that we must eat properly, breathe properly, exercise properly, rest and sleep properly, and so on. There is no special food for the blood. The blood is the medium through which the food of the body is conveyed from the food tube (digestive tract) to the living cells. There is no special way of breathing or exercising for the sake of the blood. The body behaves as a whole, and the blood is one of the means of *unifying* the many different parts. At the same time it is true that the body may be injured by way of the blood, just as it may be injured by way of the mouth or the lungs.

155. Cuts and wounds. Small wounds will usually stop bleeding because of the clotting of the blood (see section 148). Formerly the festering of sores and cuts was looked upon as a normal and necessary condition of healing. Now we know it to result from the action of various kinds of microbes, some of which, at least, produce serious blood poisons (see page 303). To prevent the festering of a wound, and to prevent the invasion of the body by more injurious microörganisms, it is well to treat

every cut with an antiseptic, or sterilizing, solution. Tincture of iodin or alcohol or carbolic acid or bichlorid of mercury may be used. The cut should then be covered with clean cotton or gauze, to prevent the entry of microbes.

With large wounds it is sometimes necessary to use special means to stop the bleeding. If the flow of blood is too strong, it may prevent the clot from holding to the sides of the wound.

Fig. 97. Treating a cut

When the pressure of the thumb is not sufficient to compress the blood vessels and stop the flow, a tourniquet may be used, made by tying a handkerchief about the limb and twisting it tight by means of a stick slipped under the handkerchief. Of course, the tourniquet or the bandage applied in this way is to be considered an emergency measure, and steps should be taken to have the wound attended to by a physician

When the flow is from an artery (which can usually be recognized by the *pulsation*), the limb should be tied *above* the cut, that is, on the side *toward* the heart. When the flow is from a vein, the attempt to stop the flow should be made on the side *away from* the heart (see Fig. 97).

156. Nose bleeding. In very many cases nose bleeding can be stopped by snuffing cold water. The old-fashioned remedy of

dropping a key down the person's back rested on the fact that the sudden chill causes the capillaries to contract. A piece of ice applied for a few moments to the back of the neck will be more likely to have the desired effect. Where bleeding continues after such simple treatment it is probable that some small artery has been broken, or that the person's blood is incapable of clotting. An *astringent* is then advisable. Powdered alum, tannin, or ferric chlorid may be applied on a tuft of cotton. These substances cause the fine blood vessels to contract, and thus stop the bleeding. In extreme cases a physician will use adrenin, an extract of the glands lying close to the kidneys (see page 177).

157. Increase in heart disorders. For a number of years past the records show that there is a steady increase both in the number of people who die as a result of some defect or failure of the heart and in the number of young people who suffer from some form of heart trouble. The reasons for this condition are not very clear. It is possible that one large source of heart trouble among young people is the fact that improvements in the medical arts have saved the lives of many boys and girls who would otherwise have been killed by various common diseases, such as scarlet fever and diphtheria. In many cases these diseases leave as an after-effect a more or less serious injury to the heart. Another source of heart trouble (besides the special diseases) is in the poisoning of the system by bacteria that do not cause special diseases. Decaying teeth, abscesses, and rheumatism would come in this class. Tobacco is known to cause irregularity in the heartbeat in young people. There are also strains and overwork for many people, as well as unsuitable diet. Athletic enthusiasm in many cases leads to an overtraining of the heart. As a result the heart is either too strong in proportion to the normal life of later years or leaves a needlessly large area exposed to injury. Defects of the heart are of two types: (1) deterioration of the valves, usually resulting from some infection or disease; and (2) a deficiency in the muscle.

The veins and arteries are also subject to special disorders. Varicose veins are those in which the walls and valves have deteriorated, resulting in obstructions to the ready flow of blood toward the heart at these points. They are related to overstrain, and particularly to standing a great deal without sufficient exercise. Laundry workers and motormen show large numbers of cases, whereas letter carriers and others who walk about a great deal rarely suffer from this disorder. Hardening of the arteries is a more serious condition. It may be due to various infectious diseases, to alcohol, to overwork, and to malnutrition. In this condition the arteries lose their elasticity and so interfere seriously with the circulation of the blood; and they are more easily burst by a sudden increase in blood pressure.

158. Care of the heart. Every contraction of the ventricles sends a wave of pressure through the blood in the arteries. The muscular and elastic walls of the arteries "give" somewhat to this pressure, and this is the *pulse* which can be felt in any artery near the surface of the body, as at the wrist, on the temples, or directly in front of the ear. From the character of the pulse the physician can often tell a great deal about the workings of the heart and about the condition of the blood vessels. The pulse may be regular or irregular; it may be strong or weak.

A strong heartbeat would ordinarily increase the pressure of the blood inside the arteries; but if the arteries are flabby, the additional work of the heart may fail to distribute the blood properly to all parts of the body. Cold feet and hands are an indication of inadequate circulation, but the cause of this condition may be in the heart or it may be in the blood vessels.

In examining a person the careful physician, athletic director, or insurance examiner will always listen to the beating of the heart and examine the pulse and test the blood pressure. From the sounds of the heart he can tell whether there is a defect in any of the valves. A leaky heart has to do a great deal more pumping to keep the body supplied than a sound heart, since a portion of every stroke is wasted in pumping blood that goes back into the auricles.

A weak heart usually shows itself in breathlessness. If you cannot climb stairs, or take a brisk walk, or play a lively game, without getting out of breath, the trouble is more likely with your heart than with your lungs. In training for athletics one of the most important things is to acquire "wind," that is, the ability to continue severe exertions without losing breath. This is in fact a training of the heart, as well as a training in correct breathing habits. Under suitable directions one can strengthen his heart considerably by means of graded exercises in walking, running, climbing, etc. Indeed, there is the possibility of overdeveloping the heart. But giving the heart occasional severe strain is not the same as training it for hard work. A person with a weak heart should not be engaged in work that strains this organ severely.

HYGIENE OF THE BLOOD AND THE CIRCULATION

1. The relation of the blood to the health of the body
   - Supplies tissues with needed materials from outside
     - Water; food; oxygen
   - Removes wastes from living cells; removes broken-down (dead) parts; removes foreign particles
   - Distributes materials produced in special parts (hormones)
   - Counteracts foreign substances
2. The relation of different organs and organ systems to the healthy condition and effectiveness of the blood
   - Food system
   - Breathing system
   - (Excretion system)
   - Hormone system
   - (Nervous system)
3. The pulse and sounds of the heart
   - Cause of pulse
   - Character of pulse under different conditions
   - Meaning of pulse characteristics: soft; irregular
   - How "leaky heart" is recognized
   - Meaning of leaky heart
4. Treatment of bleeding
   - Cuts and wounds
     - From arteries
     - From veins
   - Nosebleed
     - How to stop bleeding
     - Precautions against infection

5. Relation of exercise to blood system
   - Exercise and appetite
   - Exercise and breathing
   - Exercise and circulation
   - Exercise and heartstrain
6. Disorders of the blood system
   - Heart defects
     - Sources
       - Infections
       - Strains
     - Kinds
       - Muscular
       - Valvular
   - Arterial defects
     - Lack of elasticity
     - Hardening (arteriosclerosis)
   - Venous defects
     - Varicose veins
   - Capillary defects
     - Walls too thin
     - Bleeding easily

QUESTIONS

1. In what sense does the blood unify the body?

2. How can you tell whether the blood at a wound comes from the veins or from the arteries?

3. How should you stop the bleeding from a wound on the face?

4. What should you do to a wound besides stopping the bleeding?

5. Is a cut more likely to clot when a person is "fighting mad" or when a person is lying still? Why?

6. How does being chilly interfere with good brain work?

7. What part does the blood play in the sick condition resulting from constipation?

REFERENCE READINGS

McCarthy, J. D. Health and Efficiency, pp. 125–134.

Hough and Sedgwick. The Human Mechanism, pp. 152–165.

Harrow, Benjamin. Glands in Health and Disease, chap. xi, The Influence of the Ductless Glands on Growth and Metabolism.

Williams, J. F. Healthful Living, pp. 235–251.

Public Health Reprint 893. Methods of Administering Iodin for Prevention of Goiter.

Red Cross, Woodcraft, or Scout manuals for first aid.

CHAPTER XIX

ELIMINATION OF WASTES

Questions. **1.** Why does an organism produce substances that it does not need? **2.** Are excretions of protoplasm injurious to living things? **3.** Have all animals kidneys? **4.** Why does a physician sometimes ask for a specimen of the patient's urine?

159. The origin of wastes in living things. Every chemical process results in the formation of substances that did not exist before. In metabolism (the chemical processes of protoplasm) some of the substances produced are related to keeping the protoplasm alive, for example, digestive ferments, and chlorophyl and other pigments. Incidentally, however, other substances are also produced, which may be of no use to the living body or to the living process. Some may even be injurious. Such substances are called *wastes* and may be compared to the sawdust of a mill, or to the smoke that goes up the chimney, or to the coal tar of a gas factory.

160. Removal of wastes from cells. We have already seen (Chap. XV) that oxidation in protoplasm gives rise to carbon dioxid, water, urea, and other waste products. These diffuse out of the cell by osmosis. In our study of photosynthesis (sect. 83) we found that one of the wastes, or by-products, is oxygen, which diffuses out of the chlorophyl-containing cells through the cell walls.

In plants water and carbon dioxid are thrown out, in the form of gas or vapor, from the parts exposed to the air. The carbon dioxid given off by the cells of the roots usually remains in solution, forming so-called *carbonic acid.* Other wastes produced by plants are not generally eliminated from the body but are more likely to be locked up in cells, where they can do no harm to protoplasm. Among the waste substances thus accumulated

in plants are various kinds of pigments, insoluble crystals, tannins (commonly found in the bark of trees and in unripe fruit), various acids, and alkaloids, gums, and resins.

The one-celled animals excrete their wastes directly into the surrounding water. In the higher animals, those that have blood and lymph, the wastes are diffused from the living cells into these conducting fluids and are then eliminated from the body through special organs.

161. The kidneys. In man and the other backboned animals the **kidneys** are the special excretory organs. Water and carbon dioxid, as we have already learned (see page 161), are excreted from the lungs, as well as small quantities of urea and possibly other organic substances. Some water, salts, and urea, with traces of other organic wastes, leave the body by way of the sweat glands (Chap. XX) ; and a certain amount of waste matter gets into the intestine directly through the lining cells, in part by way of the white corpuscles (p. 179) and in part through the secretions of the liver. From the intestine these substances are removed, together with the refuse from the food, in the *feces*. But most of the wastes given off by the body cells are taken into the blood and filtered out by the kidneys.

There are two kidneys, each about as long as the width of your hand and bean-shaped. They are located in the back of the abdominal cavity, a little lower than the stomach. The structure of the kidney is that of a *gland*, a mass of tiny tubules, branched and twisted, with a complex network of capillaries. The waste substances diffuse through the walls of the capillaries into the tubules, and the fluid (**urine**) is gathered by these tubules into a funnel-shaped hollow (see *d*, Fig. 98).

162. Hygiene of the kidneys. The kidneys work constantly, and their continuous operation is essential to the health of the body as a whole. The whole system would be quickly poisoned if the wastes were allowed to remain in the blood or the cells. Since the kidney removes wastes in solution, an abundance of water is a necessary part of the daily income. We can do little more toward maintaining the health of the kidneys than

drink plenty of water and empty the bladder often enough to prevent discomfort, which is an indication of strain. On the other hand, we may do something indirectly through attention to our diet and our exercise and our general mode of living.

An excess of proteins means an excess of urea to be filtered through the kidneys. Lack of exercise results in poor circulation, so that wastes remain in the blood a long time. Bad breathing habits add to the load upon the kidneys. Alcohol causes congestion, or clogging, of the capillaries, and in the kidneys that means delaying the removal of wastes. In short, keeping well or healthy is not the simple arithmetic of keeping a number of organs in condition. Everything of importance affects the whole organism, although it may strike now at one organ and now at another.

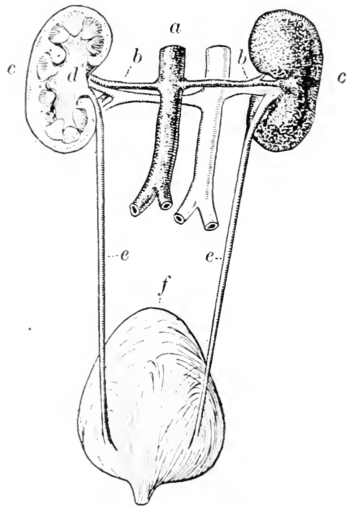


Fig. 98. Kidneys and bladder

a, the main artery, and *b*, the main vein, in the abdominal cavity, giving off branches to the kidneys *cc*; *d*, funnel-shaped cavity in which the waste fluid is gathered by the gland action of the kidney; *ee*, the *ureters*, tubes leading from the kidneys to the bladder *f*. From the bladder the urine is discharged at intervals through a tube leading to the exterior, the *urethra*. The left kidney is represented as cut through lengthwise

A generation ago every worker was allowed to quench his thirst in his own way, as best he could. The sale of beer and other prepared drinks concerned only the buyers and the sellers. Now, however, employers and managers of factories, shops, stores, and offices are finding it worth while to provide an abundance of clean, cool, and palatable drinking water. In some states the law requires that suitable drinking water be supplied in all workrooms. In a similar way, the provision of suitable toilet rooms,

which was formerly considered a mere accommodation or convenience, is coming to be recognized as a real necessity. The more progressive cities are also taking steps to provide suitable drinking water for all on the streets and in public places, as well as comfort stations for all who have to be abroad. Under ordinary conditions we give off a quart of water a day from the skin and lungs and about twice as much from the kidneys. In addition to the water that we take as part of our food, and drink with our meals, it is necessary to have access to water between meals; and in warm weather or at hard work and play the amount must be further increased.

163. Excretions as health indicators. Our knowledge of the chemistry of metabolism and of the special processes that go on within the body has been increasing rapidly. It is now possible to learn a great deal about the condition of the organism from an examination of the urine, the feces, and the perspiration and other fluids or products of the body. The amount of uric acid in the urine, the presence of carbohydrates or of albumin, bits of cells revealed by the microscope, and so on, all indicate distinct facts about what is going on in various parts of the body, not alone in the kidneys; and such information is often of importance to the physician as a means of discovering diseased conditions that might not otherwise be suspected. When a person is examined by the physician of a life-insurance company, the urine is included because very often it contains the only sign that the organism is not in good working order. Many lives are being saved by systematically examining the urine and by guiding diet, exercise, etc. accordingly.

ELIMINATION OF WASTES

1. Wastes of an organism

Sources	Kinds
Oxidation of protoplasm	Carbon dioxid
Other chemical processes	Water
	Urea
	Other compounds
	(Oxygen in green plants)

2. Excretion in one-celled organisms
   - Materials
   - How put out
3. Excretion in larger plants
   - Through leaf; through stem; through root
   - (Through locking up in inactive tissues)
4. The kidneys and bladder
   - Structure
     - Tubules and capillaries
     - Funnel
     - Ureters
     - Bladder
     - Urethra
   - Function
     - Elimination of wastes in liquid form
   - Hygiene
     - Water supply for body
     - Elimination of urine
5. Importance of condition of urine as index of condition of body

QUESTIONS

1. How do waste products originate in an organism?

2. What waste products of metabolism are harmless to protoplasm? What products are injurious?

3. What organs in a one-celled plant are analogous to the kidneys?

4. What are the advantages of taking all the water needed for the day at one drinking? What are the disadvantages?

5. Of what concern is it to the public whether stores and workshops provide suitable toilets?

REFERENCE READINGS

McCarthy, J. D. Health and Efficiency, chap. xv.
Hough and Sedgwick. The Human Mechanism, pp. 180–183.

CHAPTER XX

THE SKIN AND THE APPENDAGES

Questions. **1.** Why do people sweat? **2.** Why does the skin come to be tougher on some parts of the body than on others? **3.** What causes pimples? **4.** How can the complexion be kept clear? **5.** How often should one bathe?

164. The functions of the skin. As a covering of the whole body the skin is a protective organ, shielding the delicate tissues underneath from many possible injuries. As the point of contact between the organism and the outside world it is sensitive to various changes. It is sensitive to *touch* (which has been called the mother sense), to heat and to cold, and also to light. Contact or pressure, heat, and cold affect the nerves of the skin so that we become aware of what is going on. Light, however, does not as a rule arouse consciousness; yet we see its effect in tan and in the more painful sunburn. The skin maintains the temperature of the body (p. 168) by means of the sweat glands, through which water, salts, urea, and other organic wastes are excreted to the surface. The skin therefore serves four rather distinct functions: it is a protective, a sensory, a heat-regulating, and an excretory organ.

165. The structure of the skin and its outgrowths. The surface layer of the skin consists of *dead* cells (see Fig. 99 and Fig. 100). These horny cells are constantly rubbing off but are constantly being replaced by new cells from the live layer of **dermis** beneath. The skin is practically waterproof. Unless the epidermis is broken, it is also proof against the absorption of salts or poisons and against the entry of bacteria. Constant rubbing or pressure will cause the layer of dead cells to increase in thickness; it is thus that we acquire corns and calluses.

Embedded in the dermis, or true skin, are several distinct kinds of structures having distinct functions.

1. *Sweat glands.* A sweat gland consists of a delicate tubule opening upon the surface of the skin at one end, the pore, and twisted or coiled into a clump at the other. Surrounding the coiled end is a network of very fine capillaries, from which the water and dissolved wastes diffuse into the tube (see Fig. 101).

2. *Oil glands.* Groups of cells in the deeper layers of the dermis convert some of their food (obtained from the capillaries) into an oily substance.

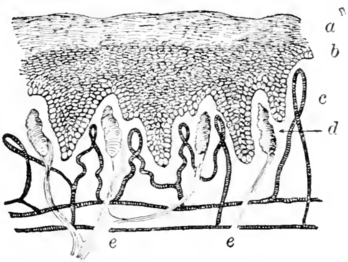


Fig. 99. Touch organs of the skin

We perceive touch or heat or cold according to the end organ which is stimulated. These end organs, *d*, lie beneath the epidermis, *a*, and contain the endings of the nerve fibers, *e*; *b*, the dermis, or true skin; *c*, blood vessels

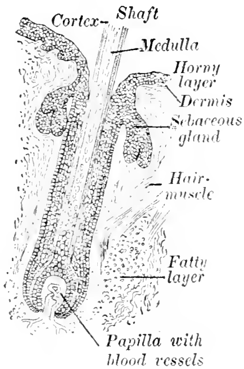


Fig. 100. Hair of mammals

Human hair follicle, showing mode of growth. The dead shaft is pushed forward by the new growth about the papilla

This oil the glands secrete on the surface of the skin all over the body, but especially at the roots of the hairs (see Fig. 100).

3. *Nerve endings.* The sense organs in the skin consist of delicate clumps of nerve tissues connected with nerve fibers. Some are sensitive to touch only, others to cold, and still others to warmth. It is probable that the amount of perspiration is controlled at least in part by the response of these nerve organs to changing temperature in the surroundings (see Fig. 99).

4. *Hairs.* Like the external portion of the skin, the part of the hair which we see consists of dead matter. The root of the

hair, the **follicle**, is a cylinder of living cells with a tiny papilla containing blood vessels (see Fig. 100). Connected with the base of the follicle are fine muscle fibers capable of raising the hairs, as in the case of the hedgehog's bristles, or in human beings under the influence of a great fright.

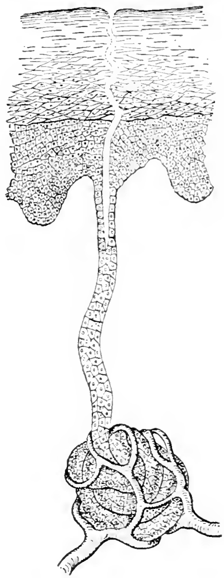


Fig. 101. Sweat gland

The sweat gland consists of a fine tubule opening to the surface of the skin at one end and coiled up in a knot at the other. The coiled portion is surrounded by blood vessels (capillaries) from which water, urea, and salts are withdrawn into the gland tube

5. *Nails.* The horny parts of the nails consist of dead cell walls formed in much the same manner as hairs. The living portion at the base of each nail forms successive layers of new cells which are pushed out, new ones taking their place.

There is usually a layer of fat cells under the skin of well-nourished persons, but fat deposits may be found in all parts of the body. Like all living tissues of the body, the dermis has blood vessels in it.

166. Appearances. It may be true that "beauty is only skin deep," but it is quite proper for us to desire good appearance. Indeed, it may be considered a duty to look as well as possible; for we all like to see *nice* people, and it is only fair for us to do our share in making the population good to look upon. A clear complexion and good color depend upon proper nutrition, vigorous circulation, plenty of oxygen, and thorough elimination of wastes. These conditions of the body are to be obtained by correct habits of eating, breathing, exercise in the open, work and play, regular movements of the bowels, etc. If our complexion does not please us, we still want it to please others. Many of us think that we have found a short cut to a good appearance by using "skin food" and massage or some other special treatment which is guaranteed to make us beautiful at least

skin deep; others find a short cut by applying a layer of beauty on the outside of the natural skin, in the form of paints and powders; but we ought to know that there is no way of feeding the skin except through the blood vessels. There is no way of removing pimples or blotches except through the blood vessels, and there is no satisfactory way of getting red cheeks except by way of the blood. All this is of course quite apart from the question of what kinds of complexions we prefer, either in ourselves or in others; that is a matter of taste.

Another aspect of appearance depends upon mental states. Drooping corners of the mouth might be concealed by an artistic make-up, but in time our habitual moods impress themselves upon our faces so that they cannot be concealed. On the other hand, it is asking too much of most people to demand cheerfulness and joyousness and good nature when they are suffering from deficient organs, from bad health habits, or from worry about their personal affairs. The remedy in such cases, however, cannot be applied to the skin.

Nevertheless, both appearance and health require that some attention be given to those parts that we show the world.

167. Care of the skin. The evaporation of the water in the sweat leaves behind salts and organic substances. Dust clings to the oil on the skin and gets into the pores. The organic wastes often have a disagreeable odor. Some people think they can remedy the disagreeable odor by the use of perfumes, but perfumes neither remove dirt nor deceive anybody as to the real need. On the contrary, we are likely to be suspicious of the person who always smells like a barber shop. If we could expose our skins to the air a great deal and rub ourselves off briskly with a coarse towel at intervals, most of us could no doubt get along very well without bathing; but the conditions under which civilized people live make bathing necessary.

A warm bath, with soap, once or twice a week, should be enough for ordinary cleanliness if there is a daily cold bath. A daily cold bath is refreshing and at the same time an excellent training for the skin in adjusting itself to changes in tempera-

ture, but it should never be taken when the body is exposed to cold air. The best time is immediately upon rising, or after vigorous work or play that has produced free sweating. Yet there are many people who cannot tolerate a cold bath because of the after-effects of the shock, and it cannot be recommended to everybody. Each one must find out for himself whether he can benefit from it. All of us can stand a splash of cold water after a warm bath, or in the morning, over the chest and back; and probably most of us can learn to stand the cold bath, either by systematically lowering the temperature of the bath day by day or by increasing the surface to which we apply cold water with a sponge. In any case the cold bath should be followed by a brisk rub with a coarse towel.

The slow, continuous perspiration, of which we are not aware, leaves deposits of wastes in the tubules of the sweat glands. More rapid perspiration washes these wastes out. Exercise that results in sweating cleans out the pores. It also increases the circulation of blood in the skin and so helps to clear the complexion and maintain the tone of the skin muscles. One of the great advantages of athletics from a health point of view is the fact that the exercise is commonly followed by a shower bath and that it makes us take a certain satisfaction in the good condition of the body. Bathing itself, aside from making for cleanliness, has also the additional virtue that it gives us a satisfying habit of feeling that the body is in good condition.

We have a special problem to keep the scalp and the hair clean and to keep up vigorous circulation in the skin of the scalp. A shampoo of pure soap or soft soap two or three times a month, with a thorough rubbing of the scalp and vigorous brushing every day, will take care of the cleanliness. A stiff brushing that reaches to the scalp and energetic work with the finger tips will be needed to insure circulation in the scalp. General exercise that induces sweating will serve the skin on the head just as it does the skin on other parts of the body.

168. Clothing. The clothes that we wear are related to our health in two different ways. They influence the work and the

condition of the skin, and so of the circulation, kidneys, and other parts of the body, and they influence our state of mind and our satisfaction with ourselves and our surroundings.

The first consideration in clothes is the relation to temperature and moisture. Woolen clothing, especially next to the skin, has the advantage that it prevents the rapid loss of heat from the body. On the other hand, it is oily and does not absorb moisture readily, so that perspiration is left on the skin. Cotton, linen, and silk also have advantages and disadvantages; no material is perfectly suited to all conditions.

For young and energetic people linen or cotton underwear of special weaves is best, all the year round, to take care of the perspiration. Even in the winter we spend most of our time (indoors) at a temperature of 65°–70° F. For cooler weather we should depend upon the outer garments for protection from excessive loss of body heat. Woolen underwear gives protection with less weight; it is therefore desirable for older people, for those who do not take vigorous exercise, and for those who are exposed for long stretches of time to cold air, whether indoors or outside. Since the underwear absorbs the perspiration, it should be aired at night and changed frequently.

We should avoid tight belts, garters, hatbands, corsets, shoes, and other articles that may compress blood vessels and so interfere with the circulation.

On the side of our mental comfort, young people are often perplexed as to whether being fashionable is worth all that it costs in the way of worry and fussing, as well as in the way of money. The fact is that one cannot afford to appear slovenly and negligent, and one cannot afford to give too much thought to the constantly changing whims of fashion-mongers and clothing designers. It is quite possible to maintain a good appearance and the corresponding satisfaction in yourself without yielding too much to the fads of the day.

169. Sunlight. One of the effects of sunlight upon the skin is to cause the formation of pigment in the dermal cells. Many of us, however, especially extreme blonds, are incapable of produc-

ing this dark pigment. Upon exposure to extreme sunshine we are apt to be burned by the rays, which cause serious injury to the exposed protoplasm. Yet the sunshine is of value in keeping up the health of the skin by promoting brisker circulation and active perspiration. It probably also produces in the skin chemical changes of a helpful kind. Moreover, the sunshine destroys many kinds of bacteria, or germs, and sun baths have been found of great value in the treatment of tuberculosis and rickets. One of the advantages of the ordinary summer vacation, with its swimming and other sports, is the increased exposure of the skin to sunshine. It is wise to expose the skin gradually and get as much tan as possible without getting sunburned.

170. The hands. The skin of the hands is always exposed to contact with dirt of various kinds, and with bacteria. We should therefore try to keep the hands as clean as possible, especially when we handle food; and we should keep them away from the mouth or eyes, which are particularly liable to suffer from an introduction of dirt or bacteria.

The chief value of our hands lies in what we can do with them as wonderful tools; but as we cannot keep them out of sight, their appearance is a matter of some concern to us. It is worth while to keep the nails well trimmed, to press the cuticle back, to cut off hangnails; it is worth while to disinfect cuts and scratches, and to keep the fingers out of the mouth, as well as other objects that do not belong there; it is important to avoid biting the nails; but it is hardly worth while to treat the hands as though they were ornaments to be exhibited.

171. The feet. While our feet are generally well concealed from the eyes of other folks, they need in some ways even more care than the hands. A very large proportion of us suffer from cramped toes and misshapen feet resulting from tight or poorly shaped shoes. Most of us suffer because our shoes do not permit the water of the perspiration to evaporate from the skin. Many people suffer from corns, which are thickenings of the epidermis resulting from constant pressure, and from bunions,

Fig. 102. High heels

The effect of high heels is to throw the leg forward and to upset the balance of the body. This results in unnecessary strains upon various muscles of the legs and trunk, and in an awkward gait

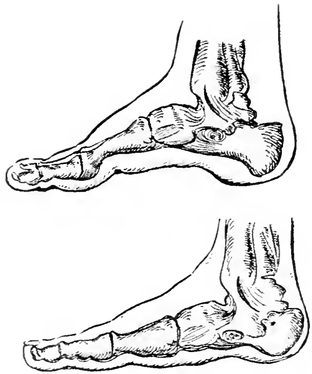


Fig. 103. Flat feet

Broken, or fallen, arches result in strains upon the leg and back muscles, often leading to headaches as well as to severe pains in the feet themselves

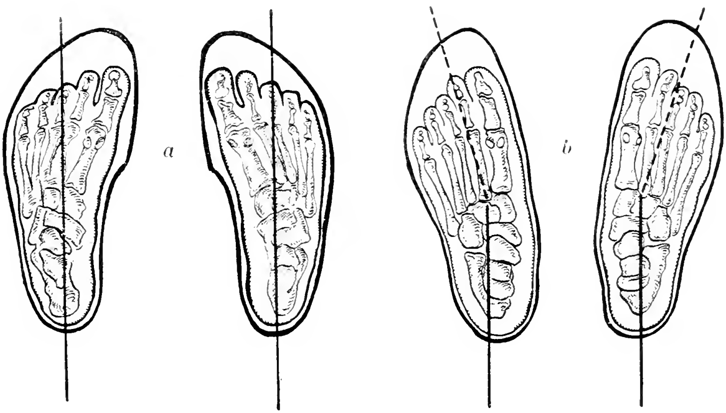


Fig. 104. Position of the feet

An important factor both in posture and in general good feeling is the position of the feet in standing and in walking. *a*, correct position. Many people get the habit early in life of spreading their toes apart, *b*, or of turning them toward each other. Both positions are bad, since they put unnecessary strains upon the leg muscles and make walking difficult

which are swellings at the joints resulting from pressure. Perhaps the most common and most serious foot troubles arise from high heels (see Fig. 102) and fallen arches (see Fig. 103).

Broken, or fallen, arches are due to a weakening of the muscles of the foot, which may result from improper shoes or from improper habits of walking. In most cases suitable exercises will lead to a strengthening of the muscles and complete correction of the defect. In other cases it is necessary to use special arch supporters, but these should be obtained only with the aid of competent physicians or foot specialists.

In walking the swing of the leg should be in a plane running directly front and back, and the line of support in the foot should move in this plane also (see Fig. 104).

THE SKIN AND THE APPENDAGES

1. The structure of the skin
    - The dermis
    - The epidermis
    - Outgrowths: hair and nails
        - Living parts; non-living parts; manner of growth
    - Glands: sweat; oil
    - Nerve endings
2. The functions of the skin
    - Protection; excretion; sensation; temperature regulation
3. Care of the skin etc.

Objects	Methods
Appearance	Cleanliness
Health	Washing
	Bathing: hot; cold
	Brushing hair

4. Hygiene of clothing
    - Advantages and disadvantages of clothing
    - Advantages and disadvantages of particular materials
    - Tight garments, belts, garters, corsets
5. Care of the hands
6. Care of the feet
    - Posture; shoes; heels; corns

QUESTIONS

1. Why is the skin on the chest more sensitive to light than the skin on the hands?

2. Why is the back of the hand usually darker than the palm?

3. How can we find out what parts of the skin are sensitive to cold and what parts to heat? What parts are most sensitive to touch?

4. Why does a surgeon wear rubber gloves when he is operating?

5. What is the advantage of vigorous sweat? What is the disadvantage?

6. What are the advantages of cold baths? What are the disadvantages?

7. What is the relation of heart action to the complexion?

8. How does the healthy condition of the kidneys and bowels influence the complexion?

9. How can the complexion be treated from the inside?

10. How does the state of mind influence a person's appearance?

REFERENCE READINGS

McCarthy, J. D. Health and Efficiency, chap. viii.
Hough and Sedgwick. The Human Mechanism, pp. 184–188; chap. xxiv, Hygiene of the Feet; chap. xxv, Bathing; chap. xxvi, Clothing.
United States Bureau of Education. Keep-Well Series, No. 12. Flat Foot and Other Foot Troubles.

CHAPTER XXI

THE UNITY OF LIFE

Questions. **1.** How are different parts of the body made to work together? **2.** Do all plants and animals have nerves? **3.** How can a slight change in one part of an organism bring about suitable responses in other parts? **4.** How can organisms that are so different from each other as the different classes of plants and animals do so many things that are exactly alike?

172. Multiplicity of life. There are probably over a million different kinds of plants and over a million different species of animals. No one person can possibly know them all; but if we consider only those that are familiar to us, it is hard to see what there is about a potato plant and about the potato beetle to make both alive, or why man and the ameba should both be considered animals. Yet throughout this endless variety there are certain *facts in common*, and it is these that make up *life*. In spite of the great variety of form and structure, all life is one in the sense that all organisms, large and small, plant and animal, ancient and modern, *all live by doing certain things*. They get food, they assimilate it after more or less change, they liberate energy by oxidizing assimilated food, and they eliminate wastes. They do other things too, but *these they all do, and in fundamentally the same way.*

173. Division of labor. Another problem that we meet when we try to locate life in an organism is the great number of organs and processes. In which one of them is life really located? Is it in digesting food or in assimilating it? in breathing oxygen or in oxidizing? Is it in the brain, where we are aware of pain and pleasure, of curiosity and fear, of joy and sorrow, or is it in the muscles or flesh, where movement, activity, work, are produced?

In the ameba and other one-celled organisms the single cell carries on all the life functions—feeding and assimilation, breathing and oxidation, movement, excretion, sensation, reproduction. Here we can say that *the protoplasm is alive.* But in a many-celled plant or animal we are not impressed by the similarity of the protoplasm in all species or in all parts of one organism; we are impressed rather by the differences between the bone cell and the gland cell and between the skin cell and the muscle cell. The ameba does *with the whole body*, so to speak, everything necessary to keep alive. A lobster or a fish does one kind of work with one organ and another kind of necessary work with another organ. This fact of having special organs for special functions has been called the *division of labor* (see section 26). The division of labor (or the *physiological* division of labor, as it is sometimes called) in plants and animals began very early in the history of living things; but it must have begun after cells began to cling to-

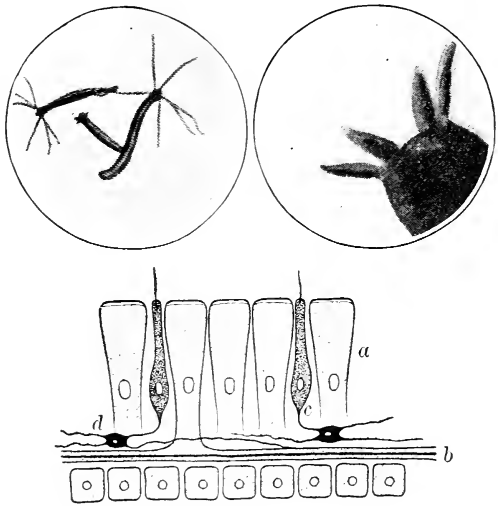


Fig. 105. Simple tissues in a simple animal

The hydra is among the simplest of many-celled animals, consisting of a hollow bag whose wall is made up of two layers of cells. There are many outgrowths around the open end. There is a division of labor between the inner layer of digesting cells and the outer layer of protecting cells. In a section of the wall we may see that the outer cells, *a*, have elongations, *b*, at their bases, which are highly contractile, and that interspersed among these cells are smaller ones, *c*, which are highly sensitive and extended into delicate threads and expansions, *d*, which may be considered to correspond to nerves. (Microphotographs lent by J. R. Bray Productions, Inc.)

gether instead of drifting apart upon being formed by the splitting of the mother cell. In the animals related to corals and jellyfish (Fig. 44) there is a beginning of this division in that the outer layer of cells shows more sensitiveness, while the inner layer is more active in digesting food (see Fig. 105). Among plants one of the earliest divisions found is that between the *vegetative* cells (those that have to do with the making of food) and the *reproductive* cells (see Fig. 106). Later divisions are seen in root and shoot; and the shoot divides into stem and leaf. The leaf divides into protective tissues and vegetative tissues; the latter again into transportation tissues and photosynthetic tissues.

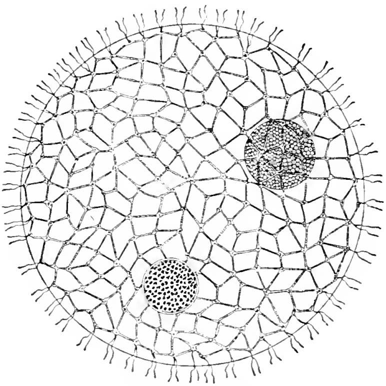


Fig. 106. Volvox

This organism consists of a hollow sphere made up of a single layer of cells connected by strands of protoplasm. The colony moves about in the water by means of *cilia*, or vibrating protoplasmic threads. Each cell contains chlorophyl. Groups of cells (represented by the dark spots) separate from the wall of the hollow sphere and produce reproducing cells

In higher animals the division of labor has resulted in the development of many kinds of organs —locomotive, protective, food-getting, food-crushing, digesting, distributing, storing, waste-removing, and so on. It is interesting and helpful to remember that in every case *function precedes structure*; that is, digestion (for example) went on in living things long before there were any digesting organs; breathing went on long before there were any gills or lungs; excretion went on before there were any kidneys; animals moved about before there were any legs or wings or fins.[1]

[1] This idea is true also if we apply it to the division of labor in society or in the community. Clothes were made long before there were any tailors; food was prepared before there were any cooks; and so on.

This means (1) that the *capacity* for these various functions is present in all protoplasm, and (2) that division of labor with the specialization of functions results from bringing together many units and giving them a chance to live together.

174. E pluribus unum. In spite of the many kinds of organs that we find in the human body and other well-developed species *the organism always acts as a whole.* The various functions, however different they may appear, are all *functions of protoplasm.* We can understand the body, perhaps, only by studying all the parts, but the several parts have no meaning except in relation to the organism as a whole. It is this unity of the organism that makes life both significant and interesting: the more complex the organism, the more varied its parts, the more wonderful is the total life in variety and interest.

Of course the human body does not come from joining together millions of cells that have once been separate. Like other organisms, it develops from a single cell that divides into two, each of which again divides, and so on until millions are formed (see Fig. 107). The many different kinds of cells and the many different organs appear gradually by a process of *differentiation*, and the different tissues and organs gradually take on *specializations* in their functions. The organism has been a unity from the first. It is only because we have taken the body apart *in our studies* that we must go a step farther and ask ourselves how the parts are kept working together.

175. How unity is maintained in higher animals. We have seen that the food-getting and digesting organs deliver the material ready for assimilation to the *blood* (see page 136); that the oxygen-getting organs deliver their oxygen to the blood (see section 136); and that all the cells of the body take from the blood the materials that they use, and throw back into the blood their wastes (see section 150). The blood system is therefore in touch with all the other systems and organs, and constantly tends to bring about a certain unity of the body, at least in a chemical or nutritional sense. The nutrition of every cell is dependent upon the condition of the blood, the oxygen

supply, and the removal of wastes—all are unified by this transportation system.

In addition to the main sets of organs already mentioned there are in the body several glands, some of them paired, which throw their special fluids directly into the blood (see section 145). These **ductless glands** are sensitive to very slight changes in the chemical condition of the blood, and in turn the substances which they discharge into the blood produce striking effects upon the protoplasm in all parts of the body.

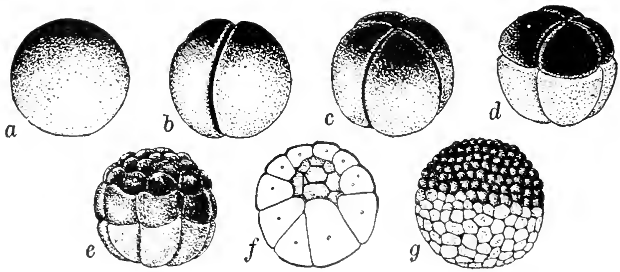


Fig. 107. Early stages in the development of a frog

The development of the frog's egg may represent for us the development in all backboned animals. The fertilized egg, *a*, divides into two cells, *b*. Each of these divides again, *c*, and the process is continued. As the number of cells increases, there soon begins a differentiation; that is, instead of the cells' continuing to be alike, some become smaller, and in time distinct regions, organs, and tissues are distinguishable

Through these *internal secretions* the strains and needs of various organs are counteracted or supplied, so that the unity of the organism is increased.

Finally, the irritability of protoplasm manifests itself in more developed animals by the formation of the *nervous system*. This reaches all parts of the body and is sensitive to changes inside, as well as to the changes and disturbances in the environment. The nerves are connected not merely with the muscles and the organs of special sensation (eye, ear, tongue, etc.) but also with the blood vessels and with the ductless glands. Because of their extreme sensitiveness and their quick response they constitute a very striking system of coördination, or unification, in the body.

176. Control in higher animals. When a simple animal adjusts itself to food particles, or escapes from an enemy, we are impressed by the *fitness* of its action. We are also impressed by the activities of a plant in relation to its surroundings. Nevertheless we cannot say that plants and simple animals act "on purpose," no matter how useful the processes are.

For one thing, we know that we can reproduce the parts of many of these processes by means of physical and chemical apparatus. For another thing, *purpose* means nothing unless we assume the presence of a mind like our own, which can have a purpose; and we cannot assume this from what we know of these organisms. Indeed, most of the acts committed by ourselves can be shown to be without purpose, even where they are of value to the organism. We therefore have no right to attribute purpose to organisms of whose minds we know nothing. What they do, like most of what we do, comes from being the kinds of organisms they are; they cannot help it.

At the same time, we know that in our own case it has been possible to select lines of conduct that do not come naturally. In so doing we obtain from the world many advantages that we should not otherwise have; or we escape many dangers or inconveniences to which we should otherwise be exposed. We find great variety in the manners and customs of different races, as well as great differences in modes of living even in our own home town. These suggest that we have a certain control both over the workings of our bodies and over our environment; or, rather, *we have a certain control over our environment by means of the control which we have over our own actions.* This control of our own activities comes from the nervous system.

THE UNITY OF LIFE

1. All life is one
    - All living things are alike
        - In depending upon certain materials and conditions
        - In carrying on certain processes
    - Everything going on in an organism is related to the life of that organism

2. Unity of life in a plant
    - Relation of various organs to the plant's life
        - Root processes
        - Stem processes
        - Leaf processes
        - Flower and fruit processes
        - Seed processes
    - Processes going on in all the organs of the plant
        - Assimilation
        - Respiration
        - Excretion
        - Cell division (reproduction)
        - Response to change
3. Unity of life in an animal
    - Relation of various organs to the life of the whole
        - Food-getting organs
        - Digestive organs
        - Breathing organs
        - Locomotive organs
        - Excretory organs
        - Circulatory organs
        - Sensory organs
        - Reproductive organs
    - Processes going on in all the organs of the animal
        - Assimilation
        - Respiration
        - Excretion
        - Cell division (reproduction)
        - Response to change
4. How unity of life is maintained in higher animals
    - The blood as a unifying system
    - The internal secretions
    - The nervous system

QUESTIONS

1. Show how different kinds of organs do the work of food-getting.

2. What is there in the butterfly that does the work of our teeth?

3. What is there in the human body that corresponds to the spiracles of an insect? In what sense do these correspond?

4. What is there in an insect's body that corresponds to the red corpuscles of our blood? In what sense does it correspond?

5. How does locomotion among insects resemble that among mammals and plants? How does it differ?

6. What advantages come to a living thing through the division of labor among organs and tissues? What disadvantages?

7. What are the conditions for a high degree of division of labor among human beings? among different nations?

8. What are some of the advantages of carrying the division of labor still farther among individuals? among nations? What are the disadvantages?

9. Is a person with a special talent better off in a large community or in a small one? Why? How about a person with a special handicap?

10. How can organisms without breathing organs breathe?

11. How can plants and animals digest without stomachs?

12. How can a man live after his stomach is removed by a surgeon?

13. How can we show that the activity of one part of the body may interfere with the full activity of another part?

14. How can we show that the activity of one part depends upon that of another?

REFERENCE READINGS

BEEBE, WILLIAM. Jungle Peace, "The Army Ants of Guiana" (extract in C. H. Ward's "Exploring Nature," pp. 96–100).

COCKERELL, T. D. A. Zoölogy, chap. vi, The Individual.

THE CONTROL OF THE BODY

CHAPTER XXII

THE NERVOUS SYSTEM

Questions. **1.** What is the use of pain? **2.** Would there be any harm in killing the nerves in the teeth? **3.** Are there any animals that have no nerves? **4.** Do animals feel pain as we do? **5.** Are there any activities in the body that we cannot control? **6.** What is the use of the funny bone?

177. Irritability. The irritability of protoplasm (see section 43) is the basis of our brain and nerves. There are mixtures of substances (non-living) that are exploded by a beam of light. The distinctive thing about the irritability of protoplasm seems to be that instead of exploding and going to pieces when disturbed, as dynamite does, for example, protoplasm brings about a change that on the whole tends to preserve it from further injury. It may *shrink away* from the point of disturbance; it may bring about a *chemical change* that counteracts the disturbance; it may *rearrange itself* so that the disturbance does no damage. But it cannot be said that protoplasm meets *every* disturbance in a suitable way, for it is possible to poison or kill protoplasm. We can only say that *in general what protoplasm does in response to what happens to it is more or less suited to help the organism or to save it from injury.*

178. Specialized irritability. With the division of labor in many-celled plants and animals, there is also a specialization of irritability. In our own body, for example, certain cells or tissues respond to disturbance by a rather sudden contraction. Others show that something has happened by increasing the amount of chemical change going on in them, and secreting

more of their special products, as is the case with the gland cells or with the white corpuscles. Most striking is the fact that some cells have specialized in *receiving* disturbances and in *transmitting* them—the *nerve* cells.

A flash, a sound, a push, any occurrence to which protoplasm is sensitive is called a **stimulus**. The contraction, the turning aside, the scream, or whatever it is that the organism does when it is *stimulated*, is called the **reaction** or the response.[1] In the highest animals, like ourselves, we recognize three distinct types of reaction:

1. *Muscle*. A stimulus may set up *movements*. Some of these we can see in the limbs, the trunk, the face, and so on; others take place in the heart, in the walls of the intestine, and so on (see Fig. 108). A sudden noise may startle one so that the whole body is visibly shaken; in another case one may keep his outward composure, yet react by a change in the heartbeat.

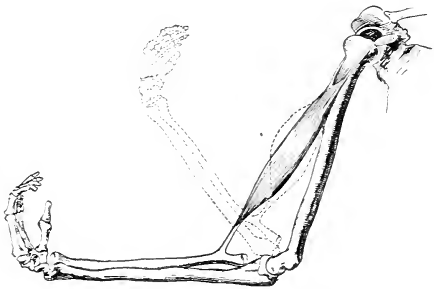


Fig. 108. Contraction of a muscle

The movement of an organ, as the forearm, is brought about by the contraction of a muscle. The mass of muscle cells becomes shorter and thicker, the parts to which its ends are attached being brought closer together. The movement of the muscle is set off by a nerve, not shown

2. *Gland*. A stimulus may set up reaction in one or more glands. The odor of well-liked food starts the salivary glands

[1] Note that the relation between the stimulus and the reaction is not of the same kind as that between the pushing of an object and its sliding or falling. In the latter case the object moves in direct proportion to the strength of the push that was applied to it. In a living organism the stimulus may represent a very slight amount of energy, while the reaction may involve a very great amount of energy. A slight touch on the sole of a man's foot may bring forth a violent kick. The relation between stimulus and reaction, so far as the *amount* of energy is concerned, can better be compared to the relation between the pressure on the trigger and the explosion of the gun.

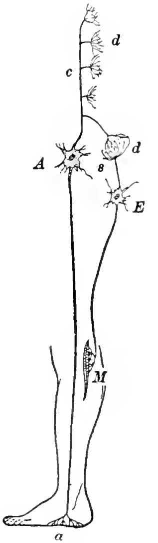


Fig. 109. Reflex arc

Stimulation of the receiving end *a* of an afferent nerve *A* leads to a discharge of energy to all parts of the neuron, including the fine terminals, or *dendrites*, *d*. The discharge passes over to connected nerves, as the *efferent* nerve *E*, by way of the interlacing dendrites, or *synapse*, *s*. The discharge in *E* leads to stimulation of the organ with which it is connected, as a muscle *M*. Starting from *a*, in the spinal cord the disturbance is reflected by one of the side branches, or *collaterals*, *c*, of *A*, through the synapse *s* into *E*, leading to a movement by the contraction of *M*

working. A lowering of the amount of sugar in the blood starts the liver discharging more glycogen. The sight of a ghost increases the flow of sweat from the skin glands.

3. *Nerve.* Sometimes a stimulus fails to bring about an *immediate* reaction, but produces instead some change in the nerve cells of the brain. You hear a word, one of many used in sentences—a lecture, a scolding, the rules of a game. You do nothing about it, apparently, at the time, but later you give evidence that the word had an effect: you recall the word when needed, you do what you were told to, and so on.

The whole behavior of a man or an ameba could be described as a system of reactions to stimuli. We cannot always recognize the stimulus; we cannot always discover the connection between the stimulus and the reaction; nevertheless both the single cell of the ameba and the nervous system of man, made up of many millions of cells, can best be understood in this way.

179. Reflexes. When you are tickled, you draw away the touched part. When something gets close to your eye, you wink. When the illumination is suddenly increased, the pupil of your eye contracts; when it is diminished, the pupil expands. When something tickles the inside of your nose, you sneeze. When a solid particle touches the lining of your windpipe, you cough. When you chew tasty food, the glands of the stomach secrete the gastric juice. When something touches the lining of the pharynx, you swallow.

Reactions of the kind mentioned are called **reflexes.** *They take place in direct response to some stimulus*, without any intention or desire, and *they cannot be prevented.* Some reflexes are useful to the organism; probably none are injurious, although we sometimes wish we could control them. For example, a person takes something into his mouth and realizes just after it gets back of the tongue that it is poison; but he cannot help swallowing it, no matter how much he may wish to. *Vomiting*, the reverse of swallowing, sometimes takes place against our will. Like other reflexes, it is entirely beyond our control. Reflexes do not always show themselves in movement. When the funny bone is struck, we become aware of a tingling sensation in the palm of the hand. Many reflexes work out through glands, as we have already seen. Some reflexes take place in organs of which we are never conscious unless they are disordered; examples are movements in the digestive system, breathing, the heart-beat. They go on just as well during sleep as in our waking hours, and in many cases *they go on just as well in the absence of the brain* or when the connection between the organs and the brain has been cut. No matter how useful such actions or reactions appear to be, *reflexes do not represent the desires or intentions* of the organism. We do not do these things "on purpose." We do them because our nerves are connected in a certain way.

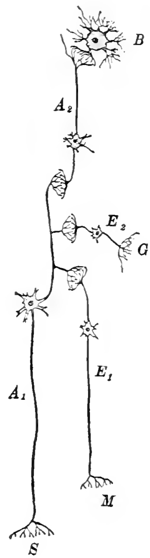


Fig. 110. Afferent and efferent nerves

Disturbance of a sense organ S, connected with an afferent nerve A_1, may set up discharges in several nerves. There may be a muscle reflex through the efferent nerve E_1, connected with a muscle; a gland reflex through the efferent nerve E_2, that is connected with a gland; and a sensation, or a feeling, through a disturbance of a brain cell B by a discharge through the connected neuron A_2

180. Nerve connections. The reflex rests upon a comparatively simple connection between (1) a nerve cell acting as a **receptor**, or stimulus-receiving structure, and (2) a muscle (or

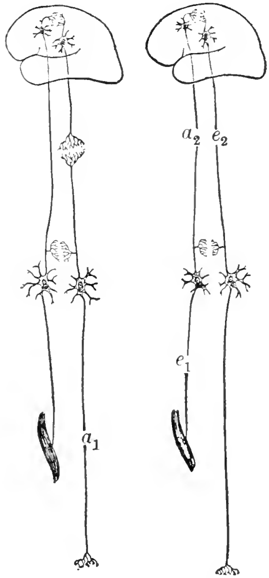


Fig. 111. Behavior limited by nerve connections

The diagram shows the nerve connections of a simple muscular reflex, with collateral connections to the brain. Such connections make possible automatic reflexes as well as voluntary movements. If the afferent nerve is cut, as at a_1, only voluntary movement is possible, and there is no sensation. If the efferent nerve is cut, as at e_1, neither reflex nor voluntary movement is possible, but sensation remains. If the spinal cord is cut high up, as at a_2, e_2, neither sensation nor voluntary movement is possible, but the reflexes are not affected

gland) acting as an **effector**, or effect-producing structure (see Fig. 109).

Nerve cells, which differ from the other cells of the body in their special irritability, have distinct structural peculiarities (see 7, Fig. 31). There are (1) a **cell body**, which contains the nucleus, and (2) outgrowths, or **fibers**, of two kinds—a long, slender fiber called the **axon**, and shorter processes that branch irregularly, like a tree, called **dendrites** (from a Greek word meaning "tree"). A nerve cell is sometimes called a **neuron**.

Neurons are found in all parts of the body, but the cell bodies are usually crowded together in special groups or regions, while the fibers are grouped into long **nerves**. The nerve-cell bodies are found chiefly in the gray **cortex**, or "bark," of the brain, in the core of the **spinal cord**, and in special groups, or **ganglia**, in various parts of the body.

The single neuron connects with other neurons through a close network formed by the dendrites and the branchings of the axon. It is not certain whether the protoplasm of one cell actually touches the protoplasm of the next in one of these connecting regions, but it is certain that the stimulation of one cell can transmit the disturbance to the next through such a connection, which is called a **synapse** (see *s*, Fig. 109). In some nerve cells a stimulation is received by the delicate branch-

ing ends of the axon and transmitted to the cell body. In other neurons the stimulus is received by the dendrites and transmitted from these to the cell body and thence on through the axon. The connection between a neuron and an effector is by means of the branching ends of either the axon or the dendrite.

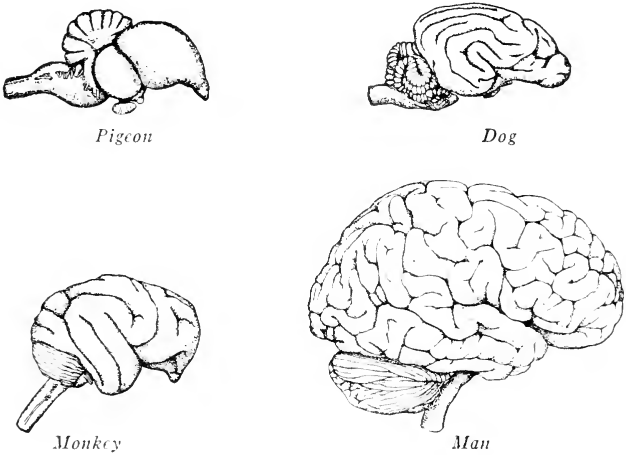


Fig. 112. Brains of vertebrates

Note the relative size of the cerebellum in the bird and mammals. In the mammals note the great increase of cerebrum and the increasing amount of convolution, or wrinkling, of the brain surface. The greater brain area in the higher animals corresponds to greater numbers of association neurons, and thus to greater intelligence

181. Kinds of neurons. Four types of neurons have been recognized, classified according to their behavior.

1. Neurons that *transmit impulses toward the brain* or spinal cord. These are called the **afferent** (bearing toward) or sensory neurons, because so many of them are connected with the sense organs on the surface of the body.

2. Those that *carry impulses from the cord or brain*—the **efferent** (bearing out) neurons. These may stimulate muscles or glands (see Fig. 111).

3. Those that *connect* afferent and efferent neurons. These may be called **associative** neurons.

4. Neurons in the brain. Many of these are not directly related to outward reactions but are related to *knowing, feeling,* and the *voluntary control of the muscles.*

Suppose a certain part of the *sciatic* nerve (the main nerve trunk running down the leg) were cut, destroying the *afferent*

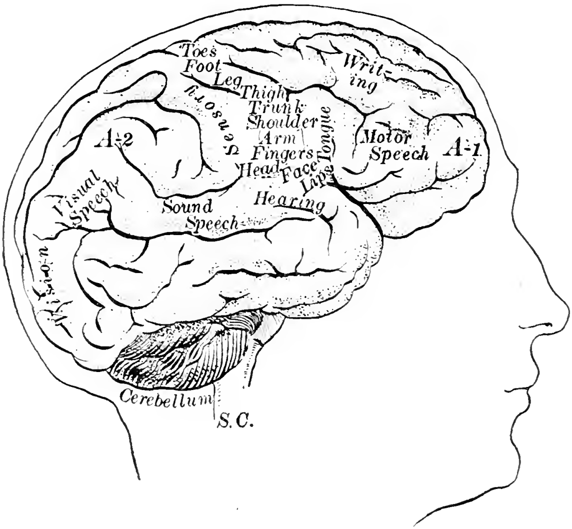


Fig. 113. Localization of functions in the cerebrum

By studying human beings and other animals in which the brain had been injured, and by making experiments, it has been ascertained that certain regions of the brain cortex are related to receiving sensations from specific regions of the body, while other regions initiate movements of specific muscles. Most of the sensory and motor nerves pass through the spinal cord. *S.C.* The thinking is carried on by the so-called association areas, *A-1* and *A-2*. The frontal association area has to do with abstract thinking, self-control, concentration, and making decisions. The hind association area has to do with knowing and understanding concrete facts and relations

fibers (a_1, Fig. 111). One might then walk on carpet tacks or hot iron and not know it, unless he happened to be watching his steps. Under these circumstances a person would be able to move his legs or to jump if he wanted to, but the reflex, or automatic, jumping would be impossible because *the arc would be broken.* On the other hand, suppose another portion of the

sciatic nerve were cut—the portion carrying *efferent* fibers (e_1, Fig. 111)—one would remain just as sensitive as ever to hot iron or tickling, but he could not move his legs, no matter how hard he tried; and certainly they would not move of themselves, for the reflex arc would be broken, as in the first case.

182. The brain. The brain of man has the same general structure as the brain of other backboned animals (see Fig. 112).[1] The brain is the front end of the main nervous axis, and contains blood vessels and connective tissue in addition to many millions of neurons. The cortex of the cerebrum (see Fig. 113) consists of nerve cells, and in mammals it is very much wrinkled. The extent of the wrinkling is related to the number of cells and to the complexity of their connections.

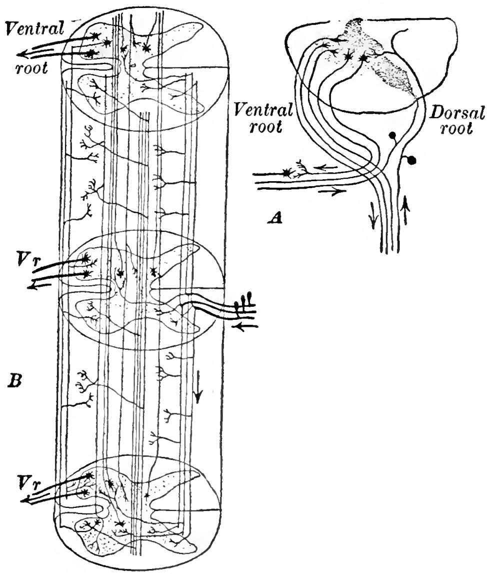


Fig. 114. Diagram of the spinal cord

A, left half of cross section, showing impulses entering the dorsal root and outgoing impulses passing out by the ventral root. *B*, the neurons connected with the gray matter of the cord give off branches passing up and down the cord and transmitting nervous disturbances by way of the collaterals. In the gray matter of the cord, branches of afferent neurons carry impulses up and down and pass them on, by way of the collaterals, to efferent neurons and to the brain

[1] Excepting the whale and the elephant, man has the largest brain; and while the brain of man is about one fiftieth of the whole body, in the elephant it represents only one five-hundredth and in the whale but one ten-thousandth.

Study of diseased or injured brains has established the fact that each portion of the cerebral cortex is concerned with some special feelings, ideas, or movements. In the diagram (Fig. 113) are indicated some of the localizations of brain function that have been determined in such studies.

All the afferent and efferent neurons related to reflexes are also connected with the brain by way of the spinal cord (see Fig. 114). When you burn your finger you withdraw your hand, *and then you feel the pain* (see Fig. 110). If you waited for action until you were aware that something had happened, it would in most cases be too late. The cerebrum has to do with conscious and voluntary action. It cannot control the reflexes, and in most cases it is not aware of them. Many of our activities and movements are unrelated to the cerebrum; but every thought, every conscious desire, and every deliberate or purposeful action depends upon impulses starting from the gray matter of the brain or leading through this gray matter.

THE NERVOUS SYSTEM

1. Irritability
    - General (all protoplasm); special (special organs or tissues)
2. Stimulus and response
    - Depends upon general irritability of protoplasm
    - Special structure for response to stimuli (reflex arc)
        - Receptor (afferent path)
        - Connector (association path)
        - Effector (efferent path)
    - Kinds of effectors
        - Muscles; glands; nerves
3. Nerve structure
    - Cell body; axon; dendrites; synapse
4. The brain
    - General structure
    - Tissues
        - Cortex
        - Association fibers
    - Connections
        - Spinal cord
        - Cranial nerves
5. Control
    - Movements and processes that are automatic and uncontrolled
    - Movements and processes that are controlled

QUESTIONS

1. How is irritability related to being alive in the case of a plant?

2. What is there in a one-celled animal that corresponds to our nervous system?

3. What useful movements does your body perform without the control of your purpose?

4. What other useful adjustments or responses does your body make without the control of your purposes?

5. What advantages would there be in being able to control these movements and processes? What disadvantages?

6. What automatic movements are performed in your body that are useless or possibly injurious?

7. What automatic movements would it be desirable to control?

8. What automatic movements can we learn to control?

9. How can we tell that reflexes depend upon nerve connections?

10. How can we tell that some nerves carry only afferent disturbances and others only efferent disturbances?

11. Under what conditions is it of advantage to an organism to be sensitive to what is happening?

12. Under what conditions is it disadvantageous to be sensitive?

13. What reflexes seem to be of no use to the body?

14. What becomes of nervous energy that is discharged by a stimulus when there is no outward movement? How can you tell in such cases that something really happens in the body, even if it does not show on the outside?

15. Of what value is it to the organism to be able to defer or postpone its reaction or to prevent an immediate reaction?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, chap. vii, The Adjustment, or Coördination, of the Work of Organs and Cells; chap. xv, The Nervous System.

Parker, G. H. Biology and Social Problems, lecture on The Nervous System.

CHAPTER XXIII

THE SPECIAL SENSE ORGANS

Questions. 1. How can some animals get along without special sense organs? **2.** Is it true that if one of the senses is injured, the others become more keen to make up for it? **3.** Why is it difficult or impossible to distinguish flavors or food when one has a cold in the nose? **4.** Are all animals equally sensitive to odors? to sounds? **5.** How can we tell whether other animals perceive the world through the senses (see, hear, smell, taste) just as we do?

183. The nervous system and the outside world. The behavior of a living thing is always related to the outside world. Indeed, life has been defined as continuous adjustment to external changes. This constant interplay between the environment and internal processes can be readily observed in very simple animals and plants. In complex organisms like the human body many things happen *on the inside* for which adjustment is necessary. For example, an increase of muscular activity calls for an increase of heart work, of lung work, and of kidney work. But that is another way of saying that the organism acts as a whole, for increase of muscular activity has to do with the outside, or the environment: it brings about changes either in the position of the organism or in the environment itself.

Many of the reflexes protect from injurious contacts or exposures, as the winking reflex, or the pupil reflex, or a withdrawing-from-pain reflex. Others serve to get the animal food. If you ever catch a fish with a hook and line, you depend upon a reflex for your success. You simply have to make sure that you have the right kind of bait; your "luck" depends upon the fish's *seeing* the bait, and the reflex does the rest.

We must not think of reflexes as *perfect* instruments for getting the necessaries or for escaping danger and enemies. From

the very nature of life there could be no such perfect instruments. Consider, for example, the fish. If the reflexes of the fish were perfect, it would always get every bit of prey for which it made a dash; and if the reflexes of the other animals were perfect, they would always escape their enemies. This, you can see, is a contradiction or impossible condition. Nevertheless we may say that most reflexes are useful to the organism.

In the lowest organisms the reactions to stimuli are of few kinds, and there is very little distinction between the effect of one kind of stimulus and the effect of another. Thus, an ameba may contract when touched, or when suddenly illuminated, or when stimulated by some chemical or by a charge of electricity. In our own bodies the division of labor has gone so far that we have several highly specialized organs, each of which is sensitive to only a limited class of stimuli.

184. The skin. In the skin are delicate nerve endings that are sensitive to slight pressure or contact (see Fig. 99). In some parts of the body the touch organs are very close together, as on the tips of the fingers and on the tongue. It seems that we perceive *heat* through the stimulation of certain end organs in the skin, and *cold* through certain others.

The disturbance, or stimulation, is carried along through the neuron and is passed on through one or more other neurons until it finally sets up a disturbance in one or more cells of the brain cortex. Here the stimulus is at last translated into a feeling, or sensation. We say that the finger is hot, but it is in the brain that we *feel* the stimulus.

185. Chemical sensitiveness. The simplest animals, like the roots of many plants, are sensitive to many kinds of chemical disturbance. We cannot suppose that the ameba, for example, has the *feeling* of sour or sweet, or that the paramecium has an idea of nice or nasty. Yet it is very plain that the protozoa are attracted by the presence of various kinds of bacteria, and that they are repulsed by various chemical substances. They will swallow the bacteria and pass sand grains by. We cannot say the "ameba likes meat juice" as we cannot say "water dislikes

oil." In both cases the reaction depends upon some relation between the composition of one body and the composition of the other body or substance. Water does not choose to dissolve sugar and to leave sand undissolved; neither can we be sure that a simple organism chooses its food, although it does take some kinds and reject other kinds of objects or materials. It is only when we come to the higher animals that we may speak of choice, and even among the highest animals most of the selecting and rejecting depends upon reflexes and instincts rather than upon thought and feeling; that is, it depends upon the structure of the organism and upon the composition of certain organs. Even in our own bodies, there are reactions to chemical stimuli similar to those of the ameba, as in the way the white corpuscles react to the presence of various kinds of bacteria that invade the body (see page 178). In addition, we have two special chemical senses, taste and smell.

186. Organs of taste. On the upper surface of the tongue, and in other parts of the lining of the mouth and of the pharynx, there are little projections called *papillæ*. These contain the nerve endings of the neurons connected with the brain cells that are aware of *taste*. The wry face that you make on tasting something disagreeable is a reflex of which the arc is formed by (1) the afferent nerves of taste and (2) the efferent nerves controlling the muscles of the lips, tongue, and cheeks. Another reflex started by taste stimuli is the watering of the mouth.

A blindfolded person, holding his nose to prevent currents of air from passing through it, cannot distinguish ground coffee, for example, from sawdust, or vanilla flavor from raspberry. When we speak of the taste of good food, we usually mean the *odor*. Our taste system can distinguish four classes of tastes: *sweet*, *sour*, *salt*, and *bitter*.

187. Organs of smell. Some of the nerve endings in the lining of the nose, and of the air passages extending back from the nose into the pharynx, are sensitive to touch; others are sensitive to odors. This specialized chemical sense is more highly developed in many of the lower animals than it is in man.

The sneeze reflex is started either by a strong odor stimulation or by a touch stimulation in some of the nerve endings in the nostrils. Watering of the mouth in response to odors illustrates reflexes that are discharged to glands rather than to muscles. The feeling of nausea and the act of vomiting are reflexes that may be started by stimulation of the odor end organs.

In both taste and smell the stimulation depends upon the presence of particular substances in direct contact with the delicate linings of the end organs. These materials must dissolve and apparently pass right to the nerve endings by osmosis.

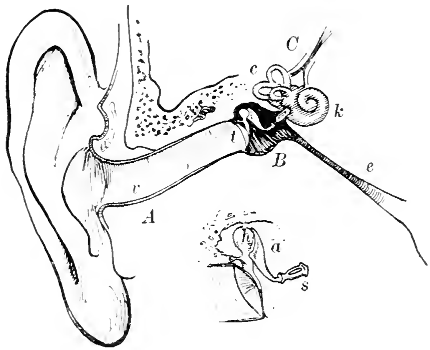


Fig. 115. The human ear

A, the outer ear, consisting of the cartilaginous projection from the side of the head and an air passage, or vestibule, *v*; *B*, the middle ear, lying between the eardrum, or *tympanum*, *t*, and the inner ear *C*. The inner ear is connected with the pharynx by the Eustachian tube *e* (see Fig. 74). Extending from the drum to the inner ear is a series of three tiny bones: *h*, the *hammer*; *a*, the *anvil*; and *s*, the *stirrup*. The main parts of the inner ear constitute the *labyrinth*: *c*, the semicircular canals, consisting of three tubes placed almost exactly at right angles to one another; *k*, the *cochlea*, or snail shell. The labyrinth is filled with a fluid and lined with a delicate membrane containing nerve endings

188. Mechanical sensitiveness. The varying pressure of bones and other structures, pressure of food in the intestine, pressure of urine inside the bladder, and other contacts and pressures within the body itself act as stimuli. Some of these touch or pressure stimuli start reflexes; others start nerve discharges that end in our being aware of conditions.

Related to these, but depending upon special organs in the inner ear, is the sensation of the position of the body and the sensation of turning or spinning, which sometimes results in dizziness. These organs consist of three tiny tubes, each in the form of a half circle, arranged at right angles to one another

(see *c*, Fig. 115). It is apparently through this organ also that we become aware of falling or dropping, and that we manage to keep our balance when walking, running, skating, etc.

Everyone who wishes to become an air pilot must take a special kind of examination for the purpose of discovering whether the balancing, or *equilibration*, reflexes are in good working order. Unless a person can respond quickly to changes in bodily position he can never learn to control a machine that moves in the three dimensions of space, and often without permitting the aid of sight (see Fig. 116).

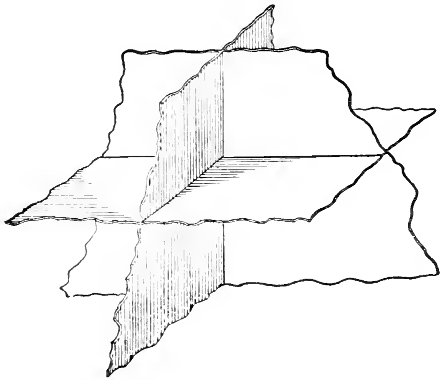


Fig. 116. The three dimensions of space

A solid body moves in a space which we think of as extending in all directions. Every movement can be thought of as a combination of movements in one or more of the three planes representing the three dimensions of space. The semicircular canals of backboned animals are placed almost at exact right angles to one another

189. Sight. Many animals are very sensitive to light without having any eyes, and many animals do not distinguish light and darkness. We know that plants and the ameba are sensitive to light. These facts mean that light is capable of modifying the processes that go on in protoplasm. Only in three of the main branches of the animal world is *seeing* possible; these are the highest mollusks, the arthropods, and the vertebrates. By seeing we mean not merely discriminating between light and dark but being able to distinguish forms and colors at some distance from objects.

Our own eye may be compared to a small camera with sensitive nerve endings in the place where the film or plate would be (see Fig. 117). The nerve endings in the retina of the eye receive impressions from vibrations in the ether at the rate of from 400,000,000,000 to 800,000,000,000 per second. If the

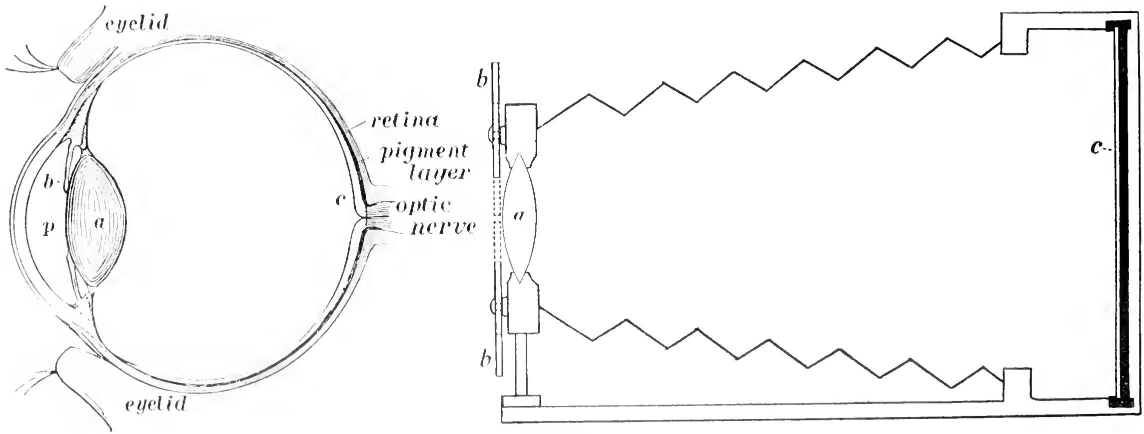


Fig. 117. The human eye compared with a photographic camera

In the eye, as in the camera, there is a lens, *a*, at one end, with a diaphragm, *b*, which is controlled by a set of muscles that are operated in a reflex way by variations in the intensity of illumination. The focusing is brought about chiefly by changing the convexity of the lens rather than by changing the distance between the lens and the sensitive surface, *c*, called the *retina*. The retina is backed up by a layer of pigment and is connected with the optic nerve. The space between the lens and the retina is filled with a transparent, jellylike mass, and in front of the lens the space under the protective coat contains a watery fluid. The eye is moved about in its setting by muscles attached to the bony framework

vibration is much more rapid or much less rapid, the nerves of the eye are not affected by them. Some insects, as ants, are sensitive to other vibrations that make no impression at all upon our retina.

190. Hearing. When the vibrations are more than from 16 to 20 per second and less than from 25,000 to 40,000 per second, the human ear discovers sounds of various pitch. In the middle register, which includes most of the sounds with which we are familiar, as the range of the human voice, the ear can distinguish very slight differences in pitch. A trained ear can distinguish more than 1000 shades of pitch in one octave.

In the air-breathing vertebrates the hearing organ is very much like our own, which is pictured in Fig. 115. A vibration striking the eardrum is transmitted through the chain of bones in the middle ear to the liquid filling the *labyrinth*. From this liquid it is transmitted to the delicate lining of the *cochlea* (snail shell), in which the nerve endings are located. Here some of the nerve endings are stimulated by vibrations of one pitch, others by those of a different pitch. The nerve fibers are connected with special cells in the brain.

Animals differ very much as to the range of sound vibrations they can perceive. Some animals are quite insensitive to sounds that nearly all human beings can hear, while some insects can perceive a much higher pitch than any human being can discover. The stretched membrane, or drum, is the receiving area for sound vibrations in many different types of animals. In some insects and spiders, however, the sound waves are received by fine stretched hairs connected with nerve fibers and by fine hairs standing out on the antennæ, or feelers.

191. The senses and adjustment. Most of the organs through which we receive stimuli from the outer world depend upon having something come in direct contact with the body. Reaction to such stimuli is ordinarily immediate—of a *reflex* character. If an animal is to profit from its ability to react to such stimuli, it must react promptly; and if the stimulus comes from possible food, then reaction must take place before the food has time to get away.

The three senses that enable the organism to obtain stimuli from objects at some distance from the body—sight, hearing, and smell—give opportunity to discover food or enemies while there is still a little time before action is imperative. We find, accordingly, that although there are many reflexes set up by these senses, there are also many situations in which *the stimulus does not bring out an immediate reaction.* The impressions obtained through these senses somehow register in the brain cells and set up activities later. It is in some such way that we are capable of *learning from experience*; the delayed reaction gives an opportunity to react in one of several different ways, and the way selected depends upon previous experience. It is probably in the delayed reaction that the organism makes a beginning at *control*—control of itself and so control of its environment.

THE SPECIAL SENSE ORGANS

1. Relation of nervous system to adjustment
   - Through reflexes
   - Through delayed reactions
   - Through acquired (learned) reactions
2. Relation of nervous system to unification of organism
   - In coördination of movements
   - In coördination of systems of organs
3. Specialized sense organs
   - Mechanical
     - Touch
     - Gravity
   - Chemical
     - Taste
     - Smell
   - Light
     - Seeing
   - Sound
     - Hearing
4. Relation of sense organs to control of environment
   - Near perception
   - Distant perception
   - Limit to perfection of reflexes

QUESTIONS

1. How do reflexes enable living things to get what they need?

2. How do reflexes enable living things to escape dangers?

3. What would happen if every animal had perfect reflexes for getting food (catching prey) and perfect reflexes for escaping enemies?

4. What use can we make of our knowledge of the reflexes of other organisms?

5. How can we make use of our knowledge about human reflexes?

6. How can we tell whether simple organisms and root hairs *choose* what they absorb?

7. How could we show that the skin is sensitive to light?

8. How can we show that leaves and stems are sensitive to light?

9. How could we show whether roots are sensitive to light?

10. How can you tell whether the distinctive quality of anything recognized through the mouth is an odor or a taste?

11. Through what organs are we capable of finding out only about things that touch the body?

12. Through what organs do we find out about things at a distance?

13. What practical use do we make of the *workings* of the semicircular canals? What practical use do we make of our *knowledge* of their workings?

14. In what ways do reflexes give organisms control over their environment?

15. In what ways do reflexes fail to give organisms control of their environment?

16. How can we tell that there are vibrations (light or sound, for example) that produce no effect upon our sense organs?

REFERENCE READINGS

HOUGH and SEDGWICK. The Human Mechanism, pp. 242–276, 395–396.
DARWIN, CHARLES. The Formation of Vegetable Mold through the Action of Worms, chaps. i and ii, Habits of Worms.

CHAPTER XXIV

HYGIENE OF THE SENSE ORGANS

Questions. **1.** Why do so many people have to wear glasses today? **2.** Why do people living in cities have greater need for glasses than those living in the country? **3.** Why are the special sense organs in greater need of protection than other organs of the body? **4.** What concern is it of the taxpayer's if some children do have defective eyesight or hearing?

192. Hygiene of the skin. The end organs of touch, heat, cold, and pain form an intimate part of the skin. Their health depends upon the general tone of the skin, the circulation of the blood near the surface, and the condition of the blood. Whatever keeps the body as a whole and the skin in good condition will serve for these organs also (see Chapter XX). We probably cannot increase the sensitiveness of our organs by anything we do, although it is possible to dull them. The extreme sensitiveness in the finger tips of a blind person probably results from learning to interpret impressions received and not from an increase in the delicacy of the nerve endings, but the congestion of the skin capillaries from using alcohol may result in false impressions regarding the temperature of the surrounding air; one may feel warm when the air is really cold.

193. Taste. The tongue, considered as a sense organ, needs no special attention to preserve its health. Disagreeable tastes in the mouth may arise from disturbances of digestion, or from the presence of decaying particles of food between the teeth. The sensitivity of the tongue may be impaired by excessive use of spices and condiments and by excessive smoking.

194. The nose. The chief source of disturbance to the sense of smell is a cold in the nose, which results in the accumulation of mucus in the nasal passages and so in an obstruction of the sensory surfaces. An additional danger of colds in the nasal

passages is that of having the affected area spread into the *sinuses* (the bone spaces of the skull), which are connected with the nostrils. The snuffing of a salt solution (a teaspoonful of salt to a pint of water) or the use of antiseptics, such as argyrol, is often helpful; but it is better in all cases to get the advice of a physician than to take any chances with these organs.

195. Hygiene of the ear. The best care to give the ear is to let it alone most of the time. When the secretion of wax in the ear tube needs to be removed, the corner of a clean handkerchief, twisted stiff, will serve. If an excessive accumulation threatens to interfere with hearing, let the physician look after it. The lining of the tube is too easily scratched, and the drum is too easily broken, to allow unskilled hands to get at them. Of course nothing should be put into the tube. If an infant gets a button or a pea into it, have a skilled person remove the intruder. The danger of ordinary children's diseases, such as measles, scarlet fever, and whooping cough, includes that of infection of the inner ear by way of the Eustachian tube, which connects the inner ear with the pharynx (see *e*, Fig. 115). There is the further danger that the infection will spread into the *mastoid* bone (the thick but spongy bone just back of the ear), and through this to the brain. Such infection is often fatal. The outer ear needs merely to be kept clean on every surface.

196. Hygiene of the eye. The eye of the higher mammals is distinctly a distance receptor, that is, an organ adapted to receiving impressions or stimuli from distant objects. But most people in civilized communities use their eyes chiefly for seeing objects or small markings at close range. The strain on the muscles that adjust the lens for far and near vision (*focusing*) often leads to headaches and irritability or nervousness. In most cases the person who suffers does not know what ails him. This kind of strain should be avoided by frequently looking away from the work, gazing out of the window for a few moments at a time, or even closing the eyes. In many cases there are imperfections in the lens of the eye or in the distance of the

retina from the lens. These errors of refraction can be corrected by suitable glasses or spectacles (see Fig. 118). As age advances the lens in many persons loses its elasticity, so that

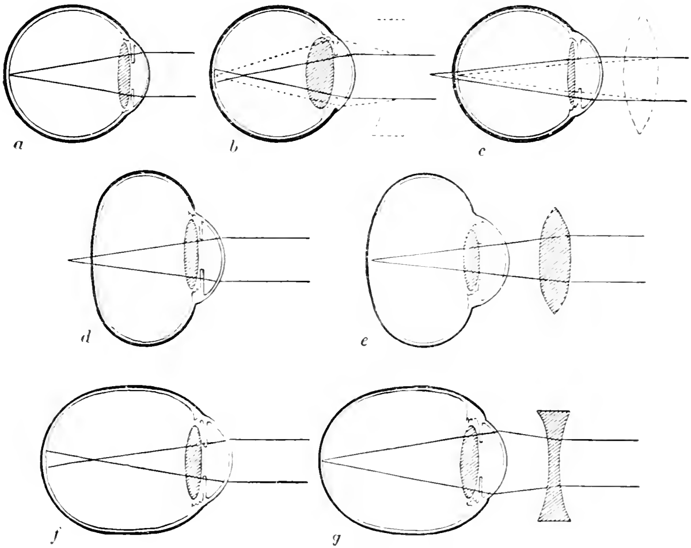


Fig. 118. Eyes and spectacles

A "normal" eye, one in which the curvature of the lens matches perfectly the length of the eyeball, *a*, is very rare. If the curvature of the lens is relatively too great the image falls in front of the retina, *b*: this near-sightedness can be made up by a concave lens of suitable curvature. Most eyes (of human beings) are far-sighted, so that the image of near objects falls behind the retina, *c*; a convex lens compensates for the flatness of the eye lens. Sometimes far-sightedness is due to extreme shortness of the eyeball, *d*; a convex lens is then necessary to bring the image forward to the retina, *e*. The opposite defect, extreme length of eyeball, *f*, is compensated by a concave lens, *g*. Spectacles do not correct defects of the eye; they can only correct the vision by compensating or making up for certain defects. Thus they can improve vision and reduce strains. (The curvatures and proportions are exaggerated in these figures)

it is necessary for those who do close work to have one pair of glasses for far vision and another for reading, sewing, and so on.

The lens surface of some eyes is uneven, so that the rays coming in are not turned equally from all parts of the field. This

condition, which is called *astigmatism*, may cause severe strain and headaches, especially with those who have to discriminate views or patterns in which lines are important, as in reading. It cannot be corrected, but can be compensated by suitable spectacles that are ground with a cylindrical surface.

Another kind of strain is the effect on the eyeballs of unequal muscular arrangement, which causes the axis of one eye to turn too far inward or outward. *Strabismus*, or squint, can be remedied by a simple surgical operation. In some cases the use of special wedge-shaped or prismatic glasses is sufficient.

If the eyes have to be examined, it is well to go to a competent eye doctor, or oculist, rather than to an optician. A scientific examination of the eyes sometimes reveals serious conditions. The optician is trained to discover shortcomings in refraction, but he is not able to discover other sick conditions. The spectacles which he prescribes may be suitable for what he finds, but they cannot help the other conditions.

Since the eye is particularly sensitive to light, incorrect illumination may affect the eye unfavorably, and through the eye the general health. Prolonged exposure of the eye to light will cause fatigue, and in extreme cases pain, discomfort, or even temporary blindness. For our daily routine we should therefore avoid work in direct sunlight, where the light can be reflected directly into the eyes. Flickering lights and sudden flashes cause injurious strains, since the iris cannot move fast enough to protect the retina from excessive exposure, and the iris reflex may become overworked. Another source of injury to the retina is *glare*, which is produced when a strong light strikes the retina while the pupil is open, or when a strong light strikes part of the retina while the rest is in comparative darkness.

The eyeball, in its bony setting, is fairly well protected from injury by large bodies, and the very quick eyelash reflex keeps many small particles out. Nevertheless many eyes are injured every year either by blows or by dust. In railroading, in the building trades, and in other dusty occupations, cinders and flying particles of metal, stone, brick, coal, etc. are sources of

serious danger to the eyes of workers. Wherever possible, workers in such occupations should wear goggles. In any case we must be careful not to rub the eye when something does get under the lid, and whoever tries to remove a particle from under the eyelid must approach the task with perfectly clean hands.

One of the dangers of getting dust into the eyes lies in the ease with which the lining of the lids becomes infected by various kinds of germs. Children suffering from trachoma and other infectious eye diseases should be excluded from school, where they are likely to transmit the disease to others. There is danger, too, in rubbing the eyes with the hands or with soiled towels or handkerchiefs. On the first appearance of an irritation or redness in the eyes it is well to wash with a solution of boric acid or argyrol; these act as safe antiseptics.

A considerable proportion of all blindness could be prevented by the exercise of greater care in dealing with injuries to the eyes, as well as by care in avoiding injuries. The largest single source of blindness is probably *ophthalmia neonatorum*, "baby sore-eyes," or the sore eyes of the newborn. This is caused by bacteria, and can be prevented by placing a drop of a 1 per cent solution of silver nitrate in each eye immediately after the birth of the child. In several states this treatment is now required of all physicians and midwives attending a birth, and in a few years thousands of persons have been saved from permanent blindness.

HYGIENE OF THE SENSE ORGANS

1. Relation to general health
   - Nutrition; circulation; respiration; excretion; exercise
2. Special precautions
   - Skin; taste; nose; ear; eye
3. The eye
   - Eyestrain
     - Causes
     - Effects
     - Prevention
     - Remedies
   - Errors of refraction
     - Near-sightedness
     - Far-sightedness
     - Astigmatism
     - (Strabismus)

Protection of eyes
- Mechanical injuries
  - Illumination
  - Glare
  - Flicker
  - Poor lighting
- Infection
  - Kinds
    - Trachoma
    - Blindness in babies
  - Prevention

QUESTIONS

1. What are the chief dangers to which our special sense organs are exposed?

2. How do modern living conditions bring special dangers to our sense organs?

3. What are the ordinary symptoms of eyestrain? How can you tell that they are due to eyestrain?

4. What are some of the advantages of properly fitted eyeglasses? the disadvantages?

5. How can difficulty in hearing affect the health?

6. What help can be found for people who are hard of hearing?

7. Why should legal regulations be established regarding the lights in public places, in factories, and on automobiles? What objections are there to such regulations?

8. What regulations (statutes or ordinances) are there in your community designed to protect people's special sense organs?

9. What arrangements are made in your school on account of the great individual variations among eyes and ears?

REFERENCE READINGS

HOUGH and SEDGWICK. The Human Mechanism, chap. xxii, The Care of the Eyes and the Ears.

Public Health Bulletin 140, Studies in Illuminations.

United States Bureau of Education. *Bulletin 65* (1919). Defective Vision, Methods of Prevention and Correction.

Supplement 8, Public Health Reports. Trachoma, its Nature and Prevention.

Bureau of Standards. Technological Paper 93, Glasses for Protecting the Eyes from Injurious Radiations.

CHAPTER XXV

INSTINCTS AND HABITS

Questions. 1. Which is more reliable, our instincts or what we learn? 2. Can people act against their instincts? 3. Have all races the same instincts? 4. Can human nature be changed? 5. Why do some people learn more easily than others? 6. Why do we learn more easily at some times than at others? 7. Why do we learn some things more easily than others? 8. Are there ways of making learning easier? 9. Can old habits be broken?

197. Instinctive acts. Among the most striking and interesting facts to be observed in animals is the precise manner in which they perform certain acts. Think of the bird making a nest, the wasp paralyzing caterpillars, bees building wax cells, a dog following a scent. In most cases the animals perform these activities perfectly *the first time they try*. Indeed, in the case of insects and many other animals, there is only one try! The wasp, for example, builds her nest, accumulates food in it, lays her eggs, and then dies, never having a chance to see her offspring, just as she never saw her parents: the animal could never have *learned* to do what it does. Such *unlearned activities* are called **instinctive**. They depend, like reflexes, upon the animal's being born with a set of nerve connections tying together receptors and effectors. In many cases we can analyze an instinctive act into a series of reflexes. In many cases the instinct shows itself when the animal is well along in its development, but nevertheless it rests upon structures that are inborn.

198. Instincts not perfect. To many people the word *instinct* suggests an act or a mode of behavior that is perfectly adapted to the needs of the animal in its environment. It is also sometimes supposed to stand for a very shrewd kind of unconscious

intelligence which enables the animal always to do what is best for it under given circumstances. That kind of "instinct" is largely a myth. A frog would starve to death with hundreds of dead worms and insects all about him, because his eating movements can be started only by *the sight of a moving object*. Or the frog will swallow a bit of cloth that is dangled in front of him, and that has no food value whatever. Again, a female fly will lay her eggs on a piece of paper that has been soaked in meat juice, although this is extremely wasteful of eggs. Of course, in a state of nature the only things that smell like meat or manure are meat and manure; and if the eggs are deposited in such materials, the young will be supplied with food. These instincts are, on the whole, beneficial, or at least not fatal, to the species.

We have seen that it is impossible for all animals to have perfect reflexes (see section 183). The same principle is true with respect to instinctive acts of all kinds. The relations of living things to one another is such that they cannot *all* get the food they need and at the same time escape being eaten by others.

199. Instincts can be modified. Eating is so fundamental to keeping alive that we should expect instinctive activities related to this process to be very well fixed in the constitution of an organism. We cannot teach a frog to eat food that is at rest, or to ignore useless dangling bait; yet eating instincts can be modified in various ways. The dog refrains from eating after he has had a good meal; that is, when he is no longer hungry, the *chemical condition* of his blood and of the other juices is different from what it was, and the "hungry" nerves and muscles behave in one way in the presence of food, whereas the muscles and nerves of an organism that is not hungry behave in a different way. If a goose has its food stuffed down the throat for several days, the animal is no longer stimulated by the sight of grain etc. to open the beak and take up food.

In an aquarium a pike was placed with a number of smaller fish. The pike swallowed his neighbors. A glass partition was then put in, separating the pike from the smaller animals. The pike would dart at them, however, and was often stunned by

striking the glass plate. But in time he stopped darting after the small fish. Later, the partition was removed; the pike would always turn aside when he approached one of the little fellows. Nothing now prevented his eating them *except his past experience.* That is to say, new connections had been formed in his nervous system, modifying his natural behavior.

200. Habit. The bruised pike shuns small fry; a burnt child dreads the fire. Acts which have unpleasant accompaniments come to be avoided; the impulse to such action becomes repressed. There is a positive side to this fact which is just as important: acts that are associated with feelings of satisfaction come to be performed more readily. This is the principle that you would use if you tried to teach a dog or a colt a trick. If you reward the animal with praise or a piece of sugar every time it does what you want it to do, it will be more likely to repeat the performance. At last it will reach a point where it is easier to perform the trick than to do what was formerly natural for it to do.

Suppose that every time a baby cries for food the mother calls to him before feeding him. At first the child will keep on crying until something actually touches his mouth. In a few days he stops crying as soon as he hears his mother's voice. Some will say that the child recognizes his mother's voice, or that he understands that she is about to feed him; but from similar observations and experiments with the young of many animals, including babies, we should rather say that the sound has become *associated* with the feeding and that the reflex has been modified by this association. A new stimulus (a particular sound) now serves as a substitute for the original stimulus to stop the crying or to start the sucking. The new mode of responding, the new trick, the modified reflex, is called a **habit.**

If you will watch yourself and others for a day, you will observe that most of our actions that are not reflexes are made up of habits. Turning to the right on passing someone is a habit. Taking off your hat on entering a house or a church, or on meeting a lady, is a habit. These things do not come natu-

rally; many people never do them at all. And they are not done "on purpose" each time, for *those who have the habit do not stop to think each time.*

201. Inhibition. The pike and the burnt baby illustrate what may be called negative habit, the habit of avoiding or repressing an action. Thus, *Don't spit!* signs are supposed to restrain the impulse to eject something from the mouth. The process of sending out a nerve impulse to stop an action started by an earlier impulse is called **inhibition**, and inhibition is just as important a part of our control as is *doing.* All movements can be performed skillfully or accurately just in proportion as a person has had practice in doing *and* inhibiting.

202. How practice makes habits. Many boys try their muscles from time to time, to see how they are coming on. This growth as a result of exercise probably comes from the facts (1) that the contraction of the muscles calls forth a reflex that increases the flow of blood, and (2) that with increased nourishment the muscle fibers increase in size or in number during the rest between exercises. The case is not so simple when the neurons are exercised. It appears that *the number of neurons does not increase after birth.* When the nervous system develops, the axons and the dendrites grow out. The outgrowths of the nerve cell have been compared to the pseudopodia of the ameba, for, like the pseudopodia, they are *extensions of the protoplasm.* Unlike the pseudopodia, these extensions cannot be withdrawn; but, like the pseudopodia, they take part in the whole life of the cell. The whole cell, including the very ends of the finest branches, acts as a unit. As a nerve cell is exercised (by receiving impressions, by sending out stimuli, or by discharging its energy in some other way) these extensions of its protoplasm are formed; and this is the basis for the *associations* that modify the conduct of the animal as it gets older.

The development of the ability to do things or to control the organs generally is thus the result of use (exercise) or disuse. With advancing age the neurons, like other cells, become less and less capable of growth and of forming new associations.

Habits acquired in youth are the most lasting, and it is for this reason that "you cannot teach an old dog new tricks."

203. Aspects of habit. It is of great practical importance to us that new nerve connections can be formed, that associations can be established, that instinctive conduct can be modified. We are thus enabled to control the lower animals and to control and enlarge our own lives. This fact is the foundation of all learning, skill, and character. The education of human beings, like the training of a dog, consists in the formation of habits—habits of doing, habits of thinking, habits of feeling.

1. *Action.* Conduct or behavior is the outward and visible manifestation of what is important about a person: we notice first of all his habits of *doing.* How does he walk or handle his food, how does he work, how does he swim or skate? We usually note the answers to such questions when we make up our minds about anybody. These habits of *doing* seem of primary importance because they determine both how *well* we do things and how *much* we accomplish. A person who could walk only by thinking of each step would not get very far in the course of a day, and he would not have much time left to accomplish anything else after he got there.

2. *Thinking.* When we learn to say (or, rather, to think) "eighty-four" on seeing "12 × 7," or when "1492" makes us think "Columbus," we are acquiring habits of *thinking.* Thinking habits show themselves when you solve problems, when you draw out of your stock of remembered ideas and experiences arguments or examples to use in a discussion, or when you plan to get certain tasks done early enough to let you go to a show. Each one of us learns through practice to do these various kinds of thinking; some of us become more skillful at one kind, some more skillful at other kinds.

3. *Feeling.* One may feel envy on seeing another person have something new, or he may feel glad that the other person has something nice, or he may enjoy the beautiful things without any relation whatever to ownership. We may have the habit of feeling contempt toward people who are different from our-

selves—people who wear different kinds of clothes, who attend a different church, or who speak with a different dialect or a different accent; or we may have the habit of feeling kindly toward strangers. Our feeling habits show themselves in the attitudes that we assume in various kinds of situations.

Our habits become so fixed and constant that they may be relied upon under nearly all circumstances. This is what is meant by *character*: it is the whole combination of habits of feeling and thinking and doing which distinguishes one person from another, or a mature person from a child. We differ very much from one another in thinking power, in strength of muscles, in endurance, and in depth of feeling; but all can acquire habits to make a character that can be depended upon, to the extent of our abilities, in all emergencies.

4. *Physiological habits.* A different class of habits is illustrated by an experiment performed on rabbits some years ago. A very small quantity of arsenic, which is a violent poison for all kinds of protoplasm, will kill a person or a rabbit.[1] In this experiment arsenic was given to rabbits in a fraction of the amount that would ordinarily kill them. After a few days the rabbits were given a little more. The dose was gradually increased until the animals had become so accustomed to the poison that they could stand several times the ordinary fatal dose. The arsenic acts upon the protoplasm of the nerves and muscles in such a way as to put the animal in a state of *tonus,* that is, the way one feels when one is "all on edge," ready to jump or scream on the slightest provocation. The rabbits thus treated became extremely sensitive to the least disturbance; they would jump on hearing the faintest sound or on the passing of a shadow. But after the animals had been treated with the poison in this way for a considerable time, *it was impossible for them to live without it.* If the drug was omitted from their daily rations, they quickly died.

Instead of establishing new nerve connections the arsenic feeding established a new *condition* of the nerves. This illus-

[1] Strangely enough, a child can stand larger doses of arsenic than an adult.

trates a very general fact about all protoplasm, or about living things. Living things can *get used* to new conditions of temperature, or of light, or of chemicals, or of food. This does not mean that every living thing can come to live in any kind of surroundings whatever. We know that is not true: birds cannot get used to living in the water, fish cannot get used to living in the air, plants and animals cannot get used to living without proteins or without salts; but the conditions of living can be changed to a certain degree or in certain directions and the organism may still remain alive. Many substances modify the activity of protoplasm in such a way that the protoplasm becomes dependent upon them. These so-called *habit-forming drugs* are dangerous not only because of the immediate injury they bring about but also because they make the victim require increasing quantities and at last make him a slave in complete dependence upon them.

204. Importance of habit. The amount of work or play that you can accomplish depends very largely upon the habits you have acquired. In dressing yourself, how many movements are necessary, and how much thought they take at first! But now you can dress yourself without thinking about the buttons and sleeves at all. We ought to be able to do all of our toilet, and a hundred other things that have to be done daily, or at least very often, without giving the actions the slightest attention. This means not only a great saving of time in doing necessary work; it means also a saving of thought for matters that are much more interesting.

The fact that animals form habits is made use of in many ways in training animals to perform tricks for our entertainment and in the everyday work of the farm or stable. By regular programs of feeding and milking cows, for example, we give them the habit of coming in from pasture when they are wanted, either at sunset or when we call them, and this saves the work of going after them; horses learn to follow fixed routes, and they learn to come home after they have strayed away; chickens come in response to a familiar call.

205. Habit as control. The control over our muscles comes from giving attention to what we are doing and then getting connections in the spinal cord to control the actions so that we do not have to think about them at all. In acquiring habits of doing, feeling, and thinking we must recognize that habits of inhibition are just as important as positive habits. We must suppress the impulse to sneer and the feeling that goes with it. We must inhibit the rising temper or the feeling of dismay. In the same way we find thoughts coming into our minds that must be put down. Castles in Spain have their proper place in life, but they must not be a-building at times that require close attention to something else. The thought of skating must be inhibited when the business of the hour calls for thinking about "dividing by fractions" or "the election of the Senate" or the designing of a dress.

Schools are established for the purpose of drilling children in the kinds of habits that grown folks believe to be useful. In addition to the habits acquired in school, each one of us gets hundreds of habits that the schools never recognize, some of them very useful, others not so useful, or even injurious. In fact, by the time a child is old enough to think about it he has gotten into so many useless habits that he has a job waiting for him, to get rid of them. Moreover, by the time we are old enough to think about it we realize that there are many things which we should have learned earlier but never did, for one reason or another; and that gives us a second big job. Better still, we can replace undesirable habits with desirable ones, and that is a large part of life, after we get to be old enough to think of such things.

As we become older our protoplasm loses the power to form new extenstion and new connections readily, but some people retain the power to form new habits much longer than others do. A part of the difference is no doubt due to the fact that some people have the habit of looking forward, of considering new ideas, of trying out new ways of doing things, and this is one of the most valuable habits we can get.

INSTINCTS AND HABITS

1. Unlearned reactions
    - Direct responses of protoplasm
    - Reflexes
    - Instincts
        - Adaptive instincts
        - Indifferent instincts
        - Adaptation not perfect
2. Modification of instincts
    - By chemical conditions
    - By experience—habit
        - Relation of feeling to habit formation
            - Pain
            - Pleasure
    - Negative (inhibition) and positive (action) aspects
    - Kinds of habits
        - Motor (muscular, action)
        - Thinking (association nerves; cortex)
        - Feeling (nerves and internal secretions)
        - (Physiological, depending upon direct reaction of protoplasm)
3. Place of instinct and habit in life
    - Reliability of instincts in natural conditions
    - Need for modification
    - Value of habit for certain kinds of activities
    - Value of retaining ability to learn
    - Habit as a means of control
        - Over our environment
        - Over ourselves
    - Habit as basis for character

QUESTIONS

1. How can you distinguish instinctive actions from acquired ones?

2. In what class of actions do people show most similarity? most difference? Why?

3. How can you distinguish instinctive actions from reflexes?

4. Why is it that the sight of certain food will make one person's mouth "water" but not another's? Why is it that certain food will make your mouth "water" at one time but not at another?

5. Why is it that you sometimes accomplish more with a small amount of practice than you do at another time with a greater amount?

6. What use can we make of our knowledge about the way different animals learn? about the way infants learn?

7. What kinds of habits have we that do not show in our conduct? How can we tell that the habits are there if they do not show in action? How can such habits be of any use or harm?

8. What are the advantages of having all habits for life fixed during childhood? the disadvantages?

9. What besides practice is necessary for fixing habits?

10. How does our environment or experience force certain habits upon us? How do our habits enable us to control our experience?

11. How can people be controlled by their habits? How can people come to control their habits?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, pp. 284–285.

Fabre, J. H. The Wonders of Instinct.

Darwin, Charles. The Formation of Vegetable Mold through the Action of Worms, chaps. i and ii, The Habits of Worms.

CHAPTER XXVI

THE EMOTIONS

Questions. **1.** Are all people naturally (instinctively) afraid of the same things? **2.** What good does it do living things to feel fear? **3.** Does fear ever interfere with adjustment? **4.** How does anger help life? **5.** Do all people naturally feel anger at the same things? **6.** Can we learn to overcome fears? **7.** Can we learn to control anger? **8.** Can we make use of our fears and angers?

206. Our double muscular system. In the simplest animals every stimulus may result in a contraction or a movement. The whole protoplasm takes part in receiving the impression and in producing the reaction. In our bodies movements are brought about by the action of *muscles* (see Fig. 108), of which there are two kinds. (1) Those with which we are most familiar (in the flesh of animals that we use as food) are attached to the bones of the skeleton and to the skin. The fibers of these muscles show characteristic cross stripes (see Fig. 119). They are sometimes called *voluntary* muscles, because we can cause them to contract at will. (2) Those muscles that are present in the inner organs—the stomach, the walls of the intestines, the blood vessels—are not striped (see *3*, Fig. 31). They are called *involuntary* muscles, because we cannot contract them at will.[1]

The striped, or skeletal, muscles hold the body in position: they make possible locomotion, grasping, getting and chewing food, directing our sense organs, and making sounds with our voice. The smooth muscles relate the parts of the body to one another. Through their activity food is moved, blood is transported and delivered, and so on. The voluntary system usually works under more or less direct control of the central nervous

[1] The muscles of the heart are *striped*, resembling those of the skeleton; but they are not voluntary, resembling those of the viscera.

system or of stimuli coming through the sense organs. The involuntary muscle system works constantly, as long as there is life, even while we are asleep. Even if the skeletal muscles are paralyzed, life may go on for an indefinite time. If the smooth muscles are paralyzed, then the end comes quickly.

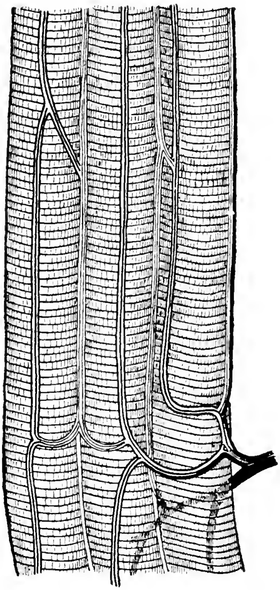


Fig. 119. Fibers of muscle

The flesh, or muscle, of animals is made up of fine threads, or fibers. Portions of three fibers are shown, with their peculiar cross stripes, and the fine blood vessels, or capillaries

207. Our double nervous system. Corresponding to the two sets of muscles we have two sets of nerves: (1) The spinal cord and the brain, with their connections to the receptors and effectors, regulate the adjustment of the organism to its surroundings. (2) The *autonomic*, or self-regulating, system connects the internal organs with one another (see Fig. 120). It has no central organ; it consists of a double series of ganglia, or nerve-cell clusters, located in front of the spinal column. Because of its many nerve connections the various activities of the organism become very closely tied together and the organism acts as a whole.

We have already seen that as the activities of the muscles and of the brain vary there is an automatic regulation of the heart, of breathing, of the blood vessels, and of various glands. This regulation is brought about by reflexes of the autonomic system. The autonomic system includes in its control, however, much more than muscles. Certain glands are of special importance in connection with the work of the autonomic nervous system.

208. Our emotions. When stimuli from the skin or some special sense organ start a nervous discharge into neurons that

connect with the cortex of the brain, we become aware, or *conscious*, of peculiar feelings, or **sensations** (see Chapter XXIII). Some of these we recognize as *hot*, *sweet*, *green*, *buzz*, and so on. But most of the stimuli and reactions of the autonomic system are entirely *unconscious*. We are not aware of a slight change in the chemical condition of the blood, such as an increase in the amount of carbon dioxid (see page 173). We are ordinarily not aware of the action of the liver and the kidneys, of the stomach and the small intestine. Sometimes, however, we do become aware of internal events, and usually in an unpleasant way. After a person has gone without food for a long time, he may have pangs of hunger, which are connected with violent contractions of the stomach. When the liver is out of order, one may feel grouchy, irritable, or pessimistic.

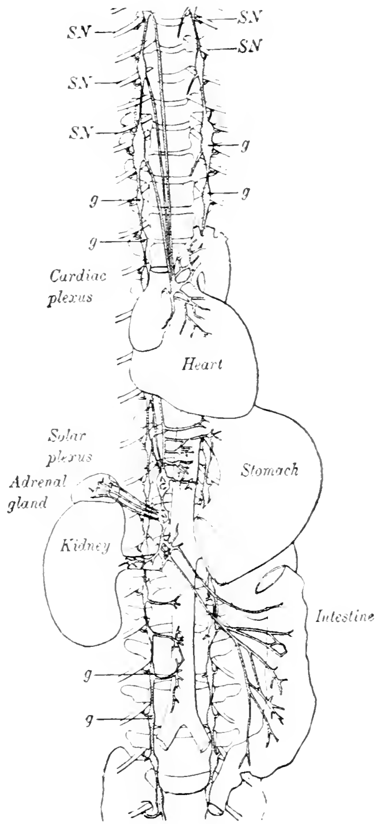


Fig. 120. The autonomic nervous system

In front of each vertebra is a pair of ganglia, *gg*, which are connected (1) with each other; (2) with the spinal nerves, *SN*; and (3) with the organs of digestion, circulation, elimination and reproduction, and the glands. The middle portion of this system, regulating the organs in the thoracic and lumbar regions, is sometimes called the *sympathetic* nervous system. Through these nerves the unconscious and involuntary processes are connected with the voluntary and conscious ones

The feelings that we have when disturbances of the autonomic system come to consciousness are called **emotions**. They differ from sen-

sations in that they cannot be *localized* or referred to a particular region of the body. We feel glad all over, or we feel angry all over, or we feel scared all over, not merely in one spot. Of course, as in the case of sensations, our being aware means probably that certain cells of the brain cortex have been stimulated.

In general, emotions accompany the organic functions that have to do with keeping one alive or preserving the species. In the case of nutrition, for example, we may become so hungry that we are driven out to get food through special effort. We are unable to keep quiet and we get no rest or satisfaction until food is procured. If the hunger makes us do something, we speak of the emotion as a *motive* or *drive*. In fact, the word *emotion* means that which *moves* to action. There may be great discomfort or dissatisfaction, a desire for something, and finally a deep satisfaction when the desire is fulfilled. We say in such cases that the emotion is one of *relief* from a previous strain.

209. Joy and sorrow. Agreeable emotions are associated with the healthy workings of internal organs and with the satisfaction of desires, or the activities that seem to satisfy the desires. The mere hearing of sounds, or the mere swinging of the arms, or the mere exercise of walking of itself, may yield such satisfactions, since they are healthy activities of the organs. Disagreeable emotions are usually associated with internal strains or with *interference* encountered by any desire or activity. If the urine is retained too long in the bladder, if somebody blocks your path, if your wishes are denied you, unpleasant feelings are aroused. Even holding a baby's head firmly, without producing any pain whatever, is enough to make him very angry. The free, spontaneous, satisfying activity, the healthy, vigorous, smooth working of the internal organs—this is the basis for the joy of living. Restraint, coercion, frustration in action, flabby, inharmonious, or perhaps even painful working of the internal organs—this is the basis of sorrow, distress, and disgust with life. Yet we must not expect a par-

ticular emotion to correspond with every instinctive act. Nor must we forget that a habit may make the same demands upon the organism as an instinctive impulse does (see section 203).

210. Expression of the emotions. The changes in facial expression which we connect with changes in people's moods are called the *expressions of the emotions.* The raising or lowering of the corners of the mouth, the pursing or curling of the lips, the lifting of the eyebrows or frowning, the bulging of the eyes or the narrowing of the eye slit are very striking and distinctive. Even a very young infant soon learns to judge the disposition of his elders by these movements of the facial muscles.

It is probably true that we may be miseducated by the extravagant or exaggerated way in which some popular actors try to register various emotions. They may thus give us not only false ideals of beauty but misleading notions of human nature and of the relative importance of the various things that happen in life.

211. Organic effects of emotions. In anger the blood is driven from the skin; one is "white with anger." At the same time the pressure of the blood in the vessels is increased; the skeletal muscles become tense; the stomach stops all work—the secretion of gastric juice as well as its muscular work. These changes are ordinarily not apparent to the observer, but they are as truly parts of the emotion as the changes that we see in the face.

When one is angry he sometimes acts violently; the blood rushes to his head, we say. Instead of thinking clearly about what he is to do or how he is to do it, he is apt to act wildly, and this peculiar conduct is also a manifestation of the emotion.

In the case of fear we may find many departures from the normal besides the facial expression. On the other hand, it is possible for one to be "consumed by jealousy" or by curiosity without showing it outwardly—at least without showing it in a way that most of us would recognize.

Aside from all the outward manifestations, and from the less apparent ones, important chemical changes take place in the

human body in connection with every emotional disturbance. Everything that modifies the normal action of any of the internal organs at once brings about an increase (or decrease) in the secretion of one or more of the ductless glands (see section 145). In anger, for example, there is a rapid increase in the output of the suprarenal capsules (which lie next to the kidneys). An injection of extract of these glands (*adrenin*) into the blood at once sets up changes similar to those observed in anger. The question may well be asked, then, whether anger is a state of mind or a chemical state of the blood. Is there anything in anger besides the outward manifestations?

We are pretty sure of this: what happens to the emotions *influences the whole body*, probably through the chemical effects of the substances from the ductless glands; and the experiences and activities of the whole body in turn modify the ductless glands and the emotions. It is said that when one is frightened and starts to run, the movements and the whole attitude of the body will tend to strengthen the fear feelings. If, on the other hand, one stands fast, clenches his fists, and takes on the posture of fearlessness, the feeling soon evaporates. This is so true that we can see every day the relation between a person's posture and his habitual disposition. The sergeant may be able to force the recruits to stand up like soldiers, but unless they get the habit of feeling like soldiers they will slump into some other way of standing as soon as the discipline is withdrawn. On the other hand, one of the best ways of getting ourselves to feel self-confidence, or generosity, or kindness is to get the habit of standing up like self-confident persons, of going through the motions or postures that belong with the feelings we wish to cultivate (see Fig. 143).

212. Emotion habits. A person cannot help becoming hungry when he has been short of food for a long time; the nature of the organism compels a certain emotion under certain conditions. But the manner of satisfying our hunger is entirely within our control. Hungry people have fought one another for food; that is one way. Hungry people have gone out to hunt

game, or they have organized work that would bring them food; that is another way. Even at the table you can see hunger driving some people into one kind of behavior and others into a different kind. These examples of the different ways in which hungry people may behave show different kinds of emotion habits as well as of action habits. In fact, *our whole manner of living* represents a scheme of habits in which emotions, thoughts, and actions are all parts of a unity. One who shows what we call breeding or good manners at table has a different set of feelings from one who shows bad manners. Both may be equally hungry. The difference in behavior represents difference in habits—feeling and thinking habits as well as action habits.

213. The formation of habits. If a baby is accustomed to feel the joy of satisfied hunger immediately after hearing a certain sound, he will soon come to have that joyous feeling on hearing the sound. If people discover that controlled anger brings more satisfaction than uncontrolled anger, they will in time find a way to control anger.

The habits that we acquire all involve feeling as well as thinking and doing. The nerves, reaching all parts of the body, are sensitive to changes and in turn bring about changes. The blood reaches all over the body: slight changes in any set of organs alter the chemical condition of the blood; slight changes in the chemical condition of the blood bring about important changes in the activity of protoplasm in all parts of the body. In this way emotions influence our thinking, our actions, and the behavior of the internal organs. On the other hand, both our thinking and our exercise of the skeletal muscles can modify our emotions.

THE EMOTIONS

1. Double system of movements in the organism
    - Related to external adjustments
        - Striped muscles (skeletal)
        - Connected with nerves from brain and spinal cord
        - Voluntary (direct control)

- Related to internal adjustments
  - Smooth muscles (visceral)
  - Connected with nerves of autonomic system
  - Involuntary (indirect control)

2. Sensations and adjustment
   - Related to stimuli
   - Related to sense organs
   - Related to cortex of brain
   - Different kinds (specific and localized)
   - Uses to organism
3. The emotions
   - Comparison to sensations
     - Resemblance
       - Appear in consciousness
     - Differences
       - Felt all over, not in special part
       - Felt in connection with types of situations, not with specific objects or stimuli
       - Cannot be readily recalled
   - Sources
     - Disturbances of autonomic nervous system
     - Chemical changes in the blood
   - Kinds (examples)
     - Pain
     - Hunger
     - Fear
     - Anger
     - Love
     - (Curiosity ?)
   - General qualities
     - Joy, or pleasurable emotion
       - From activities of sense organs
       - From activities of doing, making, etc.
       - From release of strain, satisfaction of desire, etc.
     - Sorrow, or painful emotion
       - From interference or obstruction of normal activity
       - From overworking of normal activity
       - From strain or discomfort in functions
   - Effects
     - Driving to effort or action
     - Blocking or modifying action

4. Expression of the emotions (emotion affects the whole organism, hence may show itself in any part or in all parts)
    - Skeletal muscles
        - Posture
        - Gesture
        - Facial expression
    - Internal organs
        - Breathing
        - Heart action
        - Digestion
        - Intestines
    - Cerebrospinal system
        - May cause wild action
        - May unify actions to a purpose
5. Training of emotions
    - Feeling a part of every experience
    - Feeling a part of every habit formation
    - Feeling habits formed by training in actions connected with particular feelings
    - Feeling habits determine our actions in new situations
    - Feeling habits influence our thinking

QUESTIONS

1. How does irritability help an organism get what it needs from its environment? What does it need?

2. How does irritability enable an organism to avoid or escape from dangers in its environment? What are the dangers?

3. Is everybody afraid of snakes? of thunder? of fire? of darkness? of ghosts?

4. How does one acquire fear of a particular object or stimulus?

5. Do you know any animals that are afraid of objects or conditions that are harmless? How do they show their fears? How do they get their fears?

6. Do you know any animals that become angry when there is no real need for anger? How can you tell that they are angry?

7. Under what conditions are strong feelings likely to be of help to a living thing? How?

8. Under what conditions are strong feelings likely to be a hindrance to living things? How?

9. Of what use is it to be able to recognize the feelings of other people or animals?

10. Under what conditions is it of use to show our feelings to others?

11. Under what conditions is it of use to hide our feelings from others?

12. How can we hide our feelings?

13. How can we control our feelings?

14. How can we make use of our feelings?

15. Is it desirable to suppress all feelings? Is it desirable to give immediate expression to all feelings and impulses?

16. In what ways should we be better off if we had no emotions whatever? In what ways worse off?

17. What objects arouse the feelings of people in one country but not the feelings of those in another country?

18. What kinds of emotions can we experience that are not felt by the people of other countries?

REFERENCE READINGS

WILLIAMS, J. F. Personal Hygiene Applied, pp. 309–319.

DARWIN, CHARLES. Expression of the Emotions in Man and Animals, chap. iv, Means of Expression in Animals; chap. vi. Special Expressions of Man.

CHAPTER XXVII

THE MEANING OF HEALTH

Questions. 1. Why is it important to know how different diseases are caused? 2. What is the best cure for disease? 3. What kinds of disease can be caused by the "evil eye" or by malicious wishing? 4. What disease can be cured by purely mental methods of healing? 5. Which is more powerful, the mind or the body? 6. Why do doctors prescribe drugs less than they used to?

214. Different notions about health and disease. There have always been people who suffered from some ailment or other. Perhaps nobody is *perfectly well*, although some people "ail" much more than others. The first step toward curing sick people is to know just what ails them, and the first step toward preventing illness is to know what causes illness.

People have thought that illness was caused by evil spirits getting into the body—perhaps imps or devils. In such cases the common-sense thing to do was to drive out the evil spirits or devils by making it uncomfortable for them in the body of the patient. So they would make loud, hideous sounds, or create a disagreeable odor by burning various materials, or perhaps give the patient something very bitter or nasty to take inside (see frontispiece).

Among other people the cause of disease was thought to be in a disproportion of the various juices, or "humors," of the body. Too much or too little of one juice made a person bilious or melancholy. The way to treat a person having too much juice of one kind or another was, of course, to remove the surplus. So they used to draw off some of the blood, either by cutting a vein or by means of a leech—a wormlike animal that attaches itself to the skin and sucks blood. The physician may be spoken of as a leech in some of the books that you will read. So probably

originated the red-and-white barber's pole, for the barber did the bloodletting during a long period in European history.

In another period of thought men tried to find a connection between various natural objects, like plants or animals, and the symptoms, or *signs*, of disease. The argument was something like this: Nature made everything to be of some use to mankind; the exact use does not always appear in every case, but by careful search we should find the signs that will tell us. So a plant with kidney-shaped leaves must have leaves of this shape as a sign that the plant is useful in kidney trouble. The wrinkled kernel of the walnut must have that peculiar appearance, resembling the brain, with the shell corresponding to the skull, as a sign that it is useful for brain trouble, and so on.

215. Truth in falsehood. Strange as some of these notions appear to us today, it is not fair for us to laugh at them. For one thing, what people with queer notions think seems to them just as reasonable as our thoughts do to us. For another thing, we often find that there is the possibility of at least a small grain of truth in queer notions. For example, we know today that many sicknesses depend upon the presence in the body of certain tiny plants or animals called *microbes* (meaning small living things), of which there are many kinds (see Chapter XXIX). One could say today that the notion that evil spirits cause disease is a true one if we only substitute microbes for spirits. On the other hand, these spirits cannot be driven out by beating drums or burning incense or eating bitter herbs.

In a similar way, we know from modern investigations that there are present in the body various juices (the internal secretions) which have an important bearing upon health. If one is in excess, we get one kind of disorder; if another is in excess, we get a different disorder. To be sure, these juices do not correspond to the "humors" of the ancients, but they are real juices, and some of them can be prepared in the laboratory and used for definite changes in the body to bring about cures. We do not, however, remove excess of these juices by bleeding.

Another conception of evil spirits has appeared from time to time, in which "spirit" corresponds less to a devil or an organism than to ideas or thought. Thus, many people believe that a disorder of the body may be brought about by evil thoughts, either on the part of the patient himself or on the part of some wicked enemy. This kind of belief is hard to handle, because it has to do with matters that do not lend themselves to experimenting. It would be very hard for you to prove, for example, that my toothache was *not* caused by someone's throwing toothache thoughts at me while I was asleep. Nevertheless the health of the body and the health of the mind are closely connected.

216. Physical basis of mental disturbances. Most of us are unable to keep our minds on our work when we have any kind of pain, whether it is a slight bruise or a jumping toothache. When the liver is out of order, it is almost impossible for most people to maintain a cheerful mood; we have the blues, or we are grouchy or irritable. Men have committed acts of folly and of violence when under the influence of alcohol or other drugs. When one is exhausted from hunger or fatigue, not only does the mind work at lower pressure, but there may be even uncontrolled images or wild thinking. Just as the chemical condition of the blood may change the rate of breathing and influence the digestive organs, so it may influence the brain and mental processes. People have become insane and irresponsible from the poisoning of the blood by physical disease, or by alterations in the quantities or the relative quantities of the internal secretions. So we cannot help recognizing that the mind may be influenced by physical conditions of the body.

217. Mental effects on physical conditions. Now we have to see that the opposite may be just as true. A person who is very much excited by some good news or bad news is likely to suffer from indigestion; a person who is worried is likely to become run down physically. A cheerful frame of mind keeps up the action of the blood; a hopeful disposition enables a sick person to get well more rapidly. In some cases of mental disturbance or insanity the bowels fail to carry on their work or the breathing

becomes impaired. The physical condition of the body can influence one's dreams, and certain dreams, or the reading of certain stories, can produce marked effects upon the condition of the body, such as shivering with cold or shaking with laughter. Instead of saying that *all* disorders are due to physical causes or that *all* are due to mental causes, it might be more helpful for us to think of the body as a living organism, in which every happening may influence every part.

218. Mental health and mental healing. If we realize that the organism is a unity, it is easier for us to understand that health is very largely a habit, and that the state of mind is a large part of the habit. This must not be taken to mean, however, that all illness could be prevented by proper training, or that health is to be obtained by merely getting certain ideas into our minds. It is necessary to keep the whole organism well; but if something does go wrong, it is important to find out what the cause of the trouble is. No one medicine or one trick can cure all disorders, just as no one ideal food can suit everybody all the time and just as there can be no one answer to all questions. We must guard against the idea that somebody has found a universal remedy, whether it is a kind of drug, or a kind of exercise, or a kind of lucky stone, or a kind of happy thought.

219. Health as habit. We have already seen that in order to maintain life and a sound working of the body it is necessary to provide certain materials and conditions, and we have seen that in regard to all the bodily needs that we have studied it is desirable to acquire certain habits, since there are better ways of doing things and poorer ways. Some of these desirable habits are:

1. *Habits of eating*, to get the necessary materials; to get them in the right proportions to meet the needs of the body, including the need for muscular activity of the intestines and of the jaws; to get them in the right condition to be readily used by the body, including flavor, digestibility, etc.

2. *Habits of breathing*, including constant demand for fresh air, suitable ventilation, etc.

3. *Habits of elimination*, including regularity of the bowels as well as of removal of urine, frequent perspiration, and general cleanliness.

4. *Habits of exercise*, including various kinds of work and play, to maintain circulation, breathing, elimination, etc.

There are people who get the proper food, properly prepared, in suitable quantities, who chew the food properly and have good table manners, but who nevertheless bring trouble upon themselves by occasionally putting dangerous things or substances into their mouths. Or one may disregard what happens to his eyes, or run into a moving automobile and lose a hand—or worse. Many conditions all around us demand constant vigilance if we are to avoid injuries. We might prescribe a general habit of caution, as represented by the slogan "Safety First." Being careful may be looked upon as a sort of habit, but it differs in one respect from most habits with which we are familiar. Instead of being exercised when a particular kind of stimulus reaches the senses (for example, the sight of a knife or the sound of a fire bell) carefulness is constantly at work in all sorts of situations. It is an attitude of general preparedness which many kinds of signals can change into activity.

220. Attitudes as habits. The word *attitude*, which means about the same as posture, is commonly used when referring to the posture, or position, that the mind takes in relation to the environment. This is illustrated by the close connection that we come to expect between the physical posture and the state of mind in such cases as fear, defiance, curiosity, and shame. Indeed, you can hardly pronounce these words and think of their meaning without having different muscles of your body pull toward getting your face and arms and legs and back into positions corresponding with these various feelings. As we saw in our study of the emotions (sect. 208), we have here feelings that are closely connected with all the important functions and processes of the body. Some emotions drive us to do things that we should otherwise not do at all,—such as hunger, fear, love, anger, curiosity. After some experience in infancy our

impulses to action are modified so that emotions become associated with certain actions and so keep us from doing what we otherwise feel impelled to do; for example, fear, shame, and the desire to please certain people will prevent us from doing things that we learn to regard as wrong or improper. Our emotions may be aroused by a great variety of stimuli, and they may in turn bring about a great variety of changes in the body. Anger, for example, may be aroused by an unfriendly act, or by striking an obstruction, or by seeing a bully abuse a child, or by *thinking* about the abuse of power by high officials. This feeling of anger may, in turn, bring about various changes in the expression of your face and the doubling of your fists (skeletal, or striped, muscles); it may cause a sudden flow of blood to the head and increased heartbeat (involuntary muscles); it may stop the flow of gastric juice and bring about other changes in various organs.

The manner in which we allow various happenings to stir up our feelings, and the manner in which we allow our feelings to find their way out in action, both depend largely upon habits. These feeling habits, then, are our attitudes.

221. Useful attitudes to cultivate. Since the emotions are so important in controlling organic processes, it is important for us to know how we can control our emotions. We cannot move the unstriped muscles or cause the thyroid to secrete at will. The only parts of the body that we can control voluntarily are the cortex of the brain (our thoughts) and the striped muscles that move our bones and skin. It is therefore through our thoughts and our actions that we may try to control our feelings and to establish feeling habits. If a child learns early in life to "grin and bear it," he will be able later to stand pain and to avoid crying whenever he may be hurt. If you learn to "count ten" when you are provoked, to put your hands in your pockets when they feel like striking, to press your lips together tight when certain unkind words are trying to burst out, you may find that after a while anger does not make you do what you do not wish to do. There is some truth in the statement that we are

afraid because we run away; that is at least as true as saying that we run away because we are afraid. You cannot control the palpitation of your heart and the chemical condition of your blood; you must make your effort in connection with the large muscles of running, for over these you have some control.

It seems easier to form undesirable habits, but that is because most of us do not know what we want or how to get what we want. To begin with, every child is attracted to everything he sees or hears. A useful lesson to learn early is this: *You cannot have everything.* If you choose the blue, you must go without the pink. We waste much time making a choice, and then worry because we think we might have preferred the other. There is one secret about a quick decision which many people never learn: the harder it is to make up your mind, the less does it matter, in most cases, which you choose. If it mattered a great deal, you would either recognize the difference or would learn after a few mistakes. With some people, hesitating seems to be a habit which they carry all through life. It is childish to cling to the desire to eat your cake and keep it too. Every choice means a rejection, a giving up, as well as an acceptance or taking; we cannot have one without the other. This means, in the long run, learning how to make the most of what we do get day by day instead of repining over what we might have had. Sometimes the choice is not so simple as that between two kinds of amusements; we feel strong desires to act in two ways that cannot be harmonized and that are equally pressing. It may be the desire to buy something very tempting and the desire to save for something in the future—candy now and a tennis racket later, or a bicycle now and going to college later. It may be a decision involving real sacrifice—between continuing in school and going to work to help the family, or between wearing last year's clothes to help some sick person and looking stylish to make a hit with certain persons. In such cases, too, we soon get a habit—some of us will nearly always choose immediate satisfaction, and others will nearly always choose the satisfaction of delaying for the greater object; some people never

sacrifice anything, and some never miss a chance to sacrifice. Most of us try to use our judgment in every case, but in the end we are able to distinguish two main classes of habits: (1) those of people who can find good excuses for doing what they like, and (2) those of people who can find satisfaction in doing what they think is right. In both cases we choose a satisfaction. Of course, if our habits do not fit in with the conditions in which we have to live, we are in a bad way; then none of our decisions bring satisfaction. We are, then, like people whose eating habits or thinking habits do not fit the requirements of life.

It is a good rule to choose what you want and go for it hard. Wanting everything means getting nothing. Wanting what is unattainable is getting nothing, for it is like the baby crying for the moon. Wanting things merely because others have them (covetousness, envy) means in the end cheating yourself, for even if you get them they do not satisfy, *since they do not meet your own real needs.*

222. How the mind unifies the organism. At any given moment the different processes of the body are unified by the chief activity. If you are playing a game, like basket ball or tennis, the heart and the lungs and the perspiration glands and the liver and the kidneys are adjusting their activities to the body's needs. Your senses and your muscles also are "on the stretch" to see what your adversaries and partners are doing, and to be ready to act according to the movements of the ball. You may become quite excited in the game, and everybody knows that excitement may work in two opposite ways. If you are not excited, or warmed up, enough, if you do not care enough, you will not hit hard enough; you will not see enough of what goes on to guide your movements; you will not be quick enough with your responses. On the other hand, if you are too excited, if you begin to think about the score or about possible failure, if you begin to wonder whether certain eyes are watching you, you may spoil the game by playing too wildly. In any case the body works as a whole

just as far as it is controlled by a single purpose or desire, and just in proportion to the strength of the purpose.

Habits of concentration, orderliness, and perseverance make for unity and for strength. On the other hand, habits of mind-wandering and day-dreaming, of indecision and worry, of suspicion and jealousy, of concealment and shyness, indicate a lack of unity or wholeness: and at the same time they interfere with the satisfactory coöperation of all the powers of the body in fulfilling the heart's desire. A strong will may mean the habit of holding fast to a clear picture of a definite purpose.

THE MEANING OF HEALTH

1. Ideas about sickness
    - Evil spirits get into the body
    - The humors, or juices, are out of balance
    - Something is lacking that can be supplied from a corresponding object in nature (doctrine of signatures)
    - Some part or organ is overworked or strained
    - Some part is injured
        - Mechanically
        - Chemically
    - Some part functions below or above normal
    - Evil thoughts cause sickness
        - Thoughts of the patient himself
        - Thoughts of others against the patient
    - (Parasites destroy or poison)
2. Truth fragmentary
    - Even false notions may have a trace of truth in them
    - The best knowledge that we have is never complete
    - The most useful ideas are those that lend themselves to trying out, or experimenting
3. Relations between mental and physical processes in an organism
    - Physical conditions influence mental processes
        - Pain interferes with calm thinking
        - Disordered liver prevents cheerful mood
        - Chemicals (alcohol, drugs) modify mental operations
        - Physiological conditions (hunger, fatigue) may prevent controlled conduct or thought
        - Disease may upset the mental balance

- Mental conditions influence physical or physiological processes
  - Excitement affects visceral functions
    - Digestion; breathing; heart and blood
  - Worry lowers resistance to disease
  - Cheerfulness and determination raise resistance and make more energy available
  - Mental disturbance may interfere with action of bowels and other functions
  - Fears lower metabolism
  - Thoughts and dreams affect conditions of body and actions
- The organism acts as a whole
  - Every happening influences the whole organism
  - Changes may show themselves chiefly as physical manifestations or chiefly as mental manifestations
  - Cures must be directed toward the causes of disturbance, not toward the manifestations
  - There can be no one cure for all kinds of disturbance

4. Health as a habit
   - Habits of eating (see Chapter XIV)
   - Habits of breathing (see Chapter XVI)
   - Habits of elimination (see Chapters XIX, XX)
   - Habits of exercise
     - Work and play
5. Attitudes as habit
   - Meaning of attitude
     - Position the mind takes in relation to the environment
   - Acquiring of attitudes
     - Related to the emotions
     - Fixed in connection with conduct
     - Control of feelings indirectly through striped muscles, especially the larger muscles of the body
     - Attitudes as emotion habits
   - Useful attitudes to cultivate
     - Caution
     - Quick decision
       - You cannot have everything
       - Arbitrary choices
     - Play the game hard
     - Immediate satisfaction versus deferred satisfaction
     - Principle versus expediency
     - Select your own values, not other people's; self-confidence

6. Mental habits as unifiers
    Purposes and ambitions
    Ideals (examples)

Thoroughness	Concentration	Reliability
Orderliness	Perseverance	Integrity

QUESTIONS

1. In what ways can physical conditions influence mental processes?

2. In what ways can mental conditions influence physical processes?

3. What physical processes in the body have no influence whatever upon the mind? How can we tell?

4. What mental processes have no connection whatever with physical changes? How can we tell?

5. Is it possible to be happy without health? Is it possible to be of great use without health? What is the evidence?

6. What is the advantage of patent medicines over special prescriptions by a physician? What are the disadvantages?

7. How can we tell that some ideas keep people in better health than others?

8. How is it that several persons suffering from different ailments sometimes get help from the same specialist or the same treatment?

9. How is it that several people who have the same ailments are sometimes helped by different treatments?

10. What kinds of physical habits help to keep one well? What kinds of mental habits help to keep one well? What kinds of emotional habits help to keep one well?

11. What kinds of habits can prevent disease altogether?

12. How can education promote people's health?

REFERENCE READINGS

Williams, J. F. Personal Hygiene Applied, chap. i, The Meaning of Health.
Hough and Sedgwick. The Human Mechanism, chap. xvi, Introductory to Hygiene; chap. xviii, Hygiene of the Nervous System.
Public Health Reprint 164, Mental Hygiene.

CHAPTER XXVIII

THE HUMAN ORGANISM AND KEEPING IT FIT

Questions. 1. Of what use is it to know the structure of the body? 2. Of what use is it to know about the workings of the various parts? 3. What is the use of studying the bodies of other organisms? 4. What is the use of making experiments upon the bodies of various animals? 5. How can we tell that experiments on animals have helped mankind? 6. Is it true that men have more ribs on one side than on the other? 7. How do broken bones heal? 8. How do some people come to have one leg shorter than the other? 9. Are people with large muscles healthier than people with small muscles? 10. Which is better for health, games or gymnastics?

223. Getting under the skin. A person does not need to know anything about his stomach in order to digest food properly, and some of the greatest brain workers that the world has known were totally ignorant about the nature of the brain and about its very existence; but pain and discomfort come to most people at one time or another, and in every community there are people whose chief topic of conversation is a comparison of the ailments that they "enjoy," so that someone has wittily called these frequent health discussions "organ recitals." Is it not almost a universal custom to greet people with an inquiry as to their health, and to part from them with wishes regarding their health? *Hail* (really the same as *hale*) *and farewell!* Our words *salute*, for greeting, and *valedictory*, for leave-taking, also show that the race has always had before it the problem of health, or wellness; and yet most "organ recitals" are absurd in the ignorance that people display regarding their bodies; and they are foolish too, because, instead of helping in any way, they only keep people in an unhealthy frame of mind.

Nevertheless, it is of value for all of us today to know something about the body and its workings, both (1) to help us keep

ourselves well and fit and (2) to enable us to coöperate with others in keeping the community well and fit. For many centuries even physicians were unable to become thoroughly acquainted with the structure and workings of the human body, because (1) popular superstition stood in the way of dissecting, or cutting apart, bodies for the purpose of training physicians and surgeons; and (2) almost complete reliance upon authority in all studies left students satisfied to learn what the masters handed down from generation to generation, instead of trying to learn facts at first hand. Today we are able to get more *reliable* information from books, charts, manikins, and models, and more *direct* knowledge from a study of prepared material and from dissections of other animals. It is remarkable how much we can learn even from

Fig. 121. The leopard frog (*Rana virescens*)

This common batrachian shows the general external plan of structure among vertebrates: a head with a mouth and most of the sense organs, and a trunk with two pairs of limbs. (Courtesy of American Museum of Natural History)

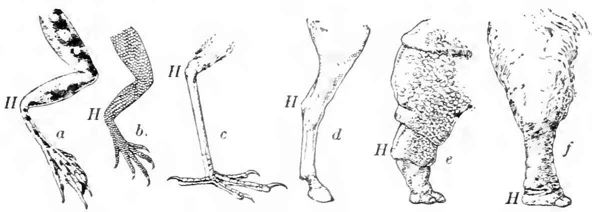


Fig. 122. Homology in hind legs of vertebrates

The hind legs of all four-footed animals and the legs of birds correspond to the paired hind fins of fishes. In spite of the many differences between them we can easily find the resemblances in the legs and feet of the frog, *a*; the lizard, *b*; the bird, *c*; the horse, *d*; the rhinoceros, *e*; and the elephant, *f*. *H* is the heel in each case

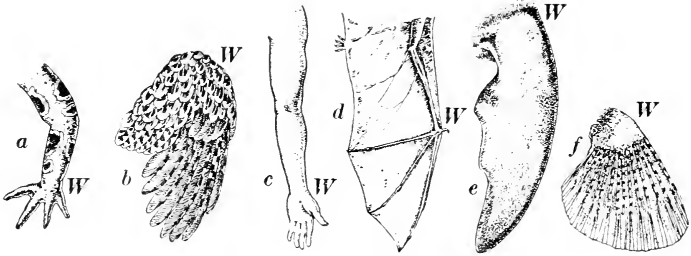


Fig. 123. Anterior limbs of vertebrates

The limbs of the different classes of backboned animals are so distinct that most people never discover that they are all different forms of the same organ. *W*, the wrist: *a*, frog; *b*, partridge; *c*, man; *d*, bat; *e*, dolphin; *f*, blackfish

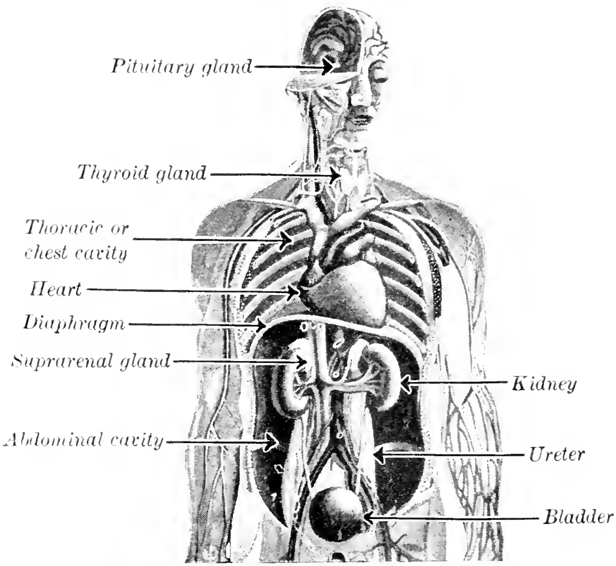


Fig. 124. The body cavity of man

In the thorax, the part above the *diaphragm*, are located the *heart* and the *lungs*, together with air vessels, blood vessels, and the part of the food tube connecting the mouth with the stomach. In the abdomen, the part below the diaphragm, are located the stomach, the liver (with the gall bladder), the small and large intestines, and the reproductive organs, together with blood vessels and special ducts. The digestive organs are not shown in this figure, but the *kidneys*, the *bladder*, and the connecting *ureter* can be seen. (Courtesy of J. R. Bray Productions, Inc.)

carving poultry or from studying the joints of meat and other materials that come from the butcher shop.

224. General plan of vertebrates. On page 16 we started to make a comparison between the human body, representing a vertebrate, and an insect body. The frog is a convenient animal for showing the general plan of vertebrates. We note the main body, or trunk, with the head at one end and with two pairs of appendages. In the more familiar groups of vertebrates (mammals, birds, amphibians, and certain reptiles such as lizards and turtles) the posterior (hind) appendages are so much alike that we generally call them by the same name—legs. To be sure, the flippers of the seal or the whale resemble the fins of fishes more than they do the limbs of land animals, and the fins of fishes do not resemble our legs or arms at all, except perhaps in their positions on the body; yet they are truly *homologous* organs (see Figs. 122 and 123). The head is easily recognized in all classes, although it is not always on a distinct neck.

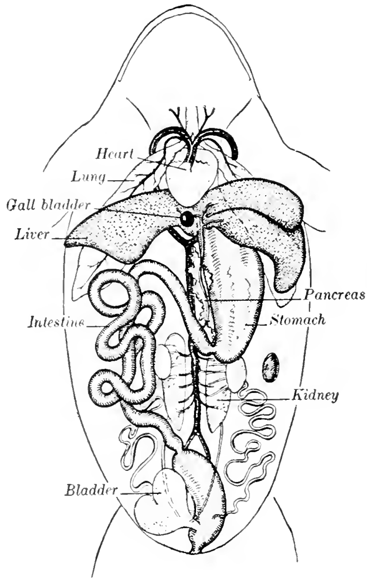


Fig. 125. The viscera of the frog

In the body cavity of the frog are located the principal breathing organs (the lungs); the principal digestive organs (stomach and intestines, liver and gall bladder, and pancreas); the principal excreting organs (the kidneys); the blood-pumping organ (the heart); and the reproductive organs (ovaries or testes). The largest blood vessels, air tubes, and connecting ducts are also in this cavity

The trunk of the frog consists of a body wall inclosing a large cavity. In the mammals, including man, the body cavity is divided into two chambers by a muscular partition called the diaphragm (see Figs. 84 and 124). Inside the cavity of the

trunk are the viscera, or the organs directly connected with the main functions of *nutrition* (including respiration, circulation, and excretion) and *reproduction* (Figs. 125 and 126).

In fishes, which have no lungs but breathe through the gills (see Fig. 186), the viscera of the digestive system lie fairly well forward (see Fig. 78). The dissolved oxygen, which is taken from the air by the water, is absorbed from the water by osmosis. Among all vertebrates there is, of course, a portion of the food tube connecting the mouth and the stomach (*esophagus*) that passes through the thorax. Among vertebrates that have no diaphragm (all classes of backboned animals except mammals) there is no sharp distinction between the thorax and the abdomen, and we find a great deal of overlapping of organs.

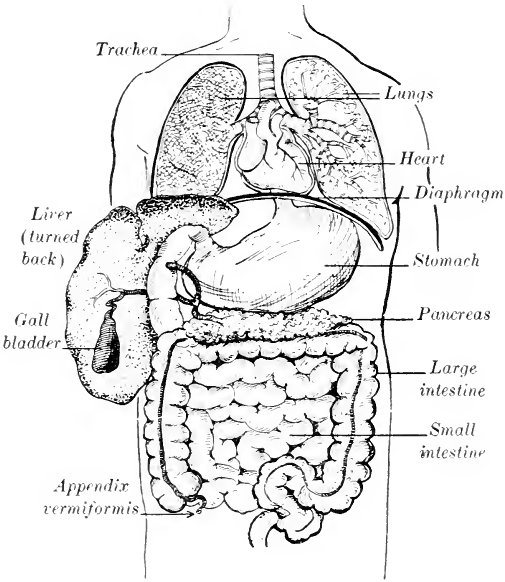


Fig. 126. The viscera of man

In all air-breathing vertebrates the internal organs have essentially the same general structure and the same general arrangement

Running through both thoracic and abdominal cavities is a double chain of nerve ganglia making up the "sympathetic nervous system" (see page 253), which lies at the very back of the cavities, in front of the spinal column.

In all except the lowest vertebrates the head carries a distinct jaw and several special sense organs, the eyes and the ears being the most prominent. The larger part of the head in man consists of the brain box, or **cranium**. In the frog you

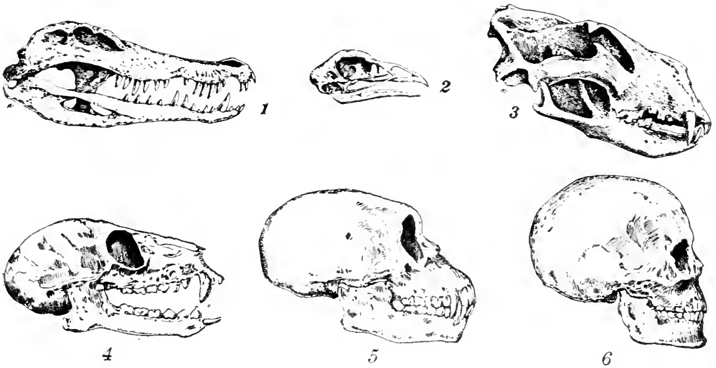


Fig. 127. Skulls of vertebrates

Compare the size of the face and jaw with the size of the brain box. Note the appearance in man of a distinct chin and a nose bridge. *1*, alligator, 18 inches long; *2*, chicken, 1½ inches; *3*, lion, 11 inches; *4*, lemur, 3 inches; *5*, gibbon, 5 inches; *6*, man, 8 inches

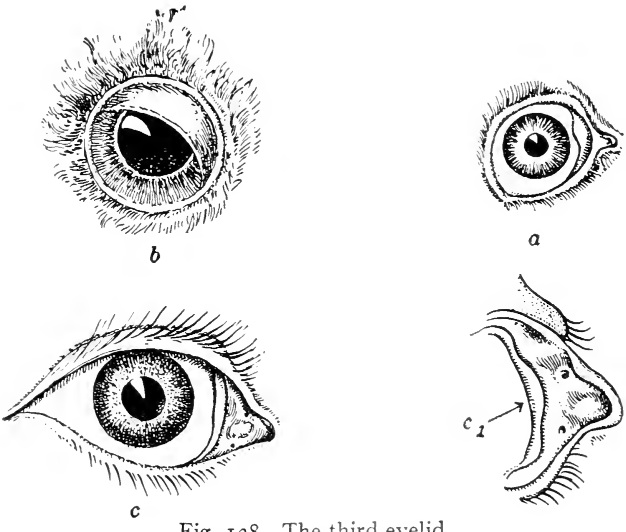


Fig. 128. The third eyelid

The little fold of tissue extending from the inner corner of the eye corresponds to the third eyelid, or *nictitating membrane*, in birds and certain reptiles and amphibians. The nictitating membrane can be drawn over the eye so as to cover it completely. *a*, eye of ape; *b*, eye of owl; *c*, human eye; c_1, the semilunar fold, eyeball removed

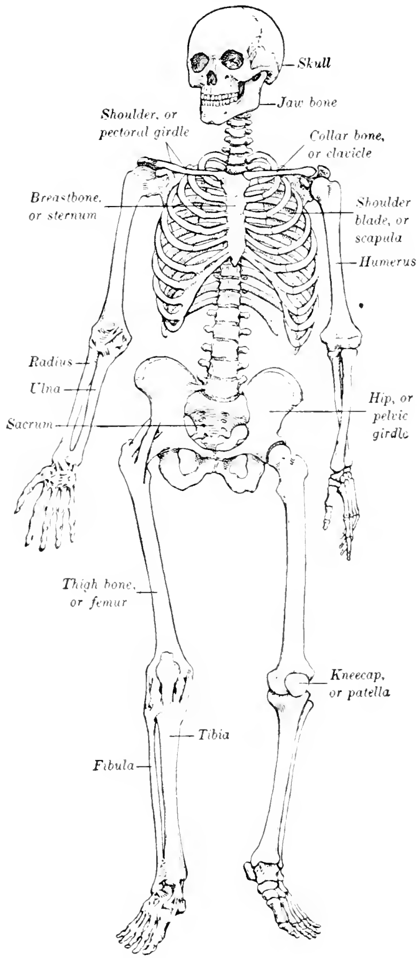


Fig. 129. Human skeleton

The skeleton consists of bones attached to one another by tough bands of connective tissue called *ligaments*. At various points bones next to each other are separated by tough, elastic pads of connective tissue, as between the parts of the vertebral column; at other points two bones that move against one another are separated by special joint surfaces that are perfectly smooth and lubricated by a fluid; at other points distinct bones appear to be fused together; and in some places the bones run into a tough tissue called *cartilage*, which is the same as the gristle in the outer ear. All the bones, together with the cartilages and ligaments, make up the skeleton

can easily see the eardrum back of the eye; there is nothing corresponding to the external ears of mammals. If you watch a living frog for a little while, you will notice something peculiar

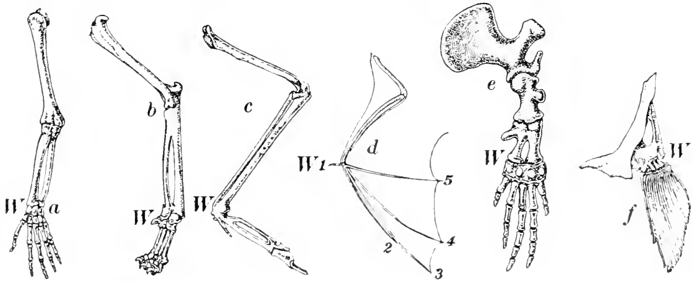


Fig. 130. Homologies in the skeletons of vertebrates

In spite of the different appearance and different functions of the limbs of backboned animals the supporting structures have the same general plan. *W*, the wrist bones: *a*, man; *b*, lion; *c*, vulture; *d*, bat; *e*, whale; *f*, halibut

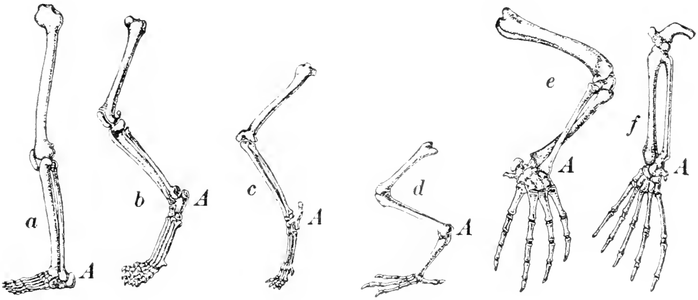


Fig. 131. Homologies in the bones of the hind leg

Walking, crawling, swimming, loping—all the various modes of locomotion found among backboned animals—are carried on by organs having the same fundamental structure. *A*, ankle bones: *a*, man; *b*, lion; *c*, wolf; *d*, duck; *e*, crocodile; *f*, seal

in the way he "winks" (see Fig. 128). Fishes have no eyelids at all, and in snakes the eyelids are always closed but transparent.

The nostrils in the frog correspond to ours and lead into the mouth cavity; they can be closed. In all vertebrates the breathing organs are connected with the mouth, but in none of the invertebrates. The tongue is a muscular outgrowth

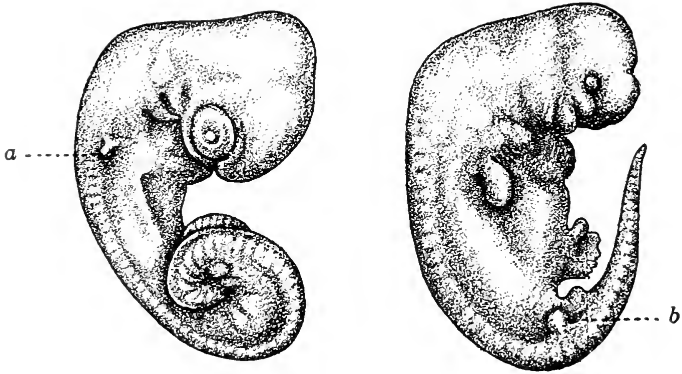


Fig. 132. Some curious but useless relics

In the glass snake, a kind of lizard (*Anguis fragilis*), the buds of the front legs are present during an early stage of development, *a*, but the fully formed animal is footless. In the porpoise (*Phocaena communis*) the buds of the hind legs (or flippers) are present during an early stage of development, *b*, but the fully developed animal has only front flippers

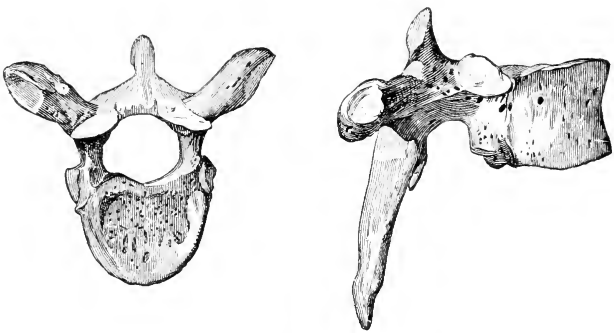


Fig. 133. Human vertebræ

Each of the units of the spinal column consists of a main body (with an arch on the dorsal side) and various projections. The openings in the arches make up a tube, or canal, in which the spinal cord lies

from the floor of the mouth, and acquires a great variety of forms and functions in different species of backboned animals; in most cases it is either a food-getting organ or one that moves food around during the process of chewing.

225. The skeleton. Among vertebrates the skeleton, the mechanical framework of the body, is an *internal* structure. This is in contrast to the insects and other arthropods (crabs, lobsters, spiders, etc.) and to the mollusks (clams, snails), which have their skeletons on the outside of the body. The general plan of the skeleton is that of the body as a whole. There is a main axis, the backbone, or **vertebral column**, extending back from the brain box, or skull, and there are two bony rings to which the *appendages* are attached—the **pectoral**, or shoulder, girdle, and the **pelvic**, or hip, girdle (see Fig. 129).

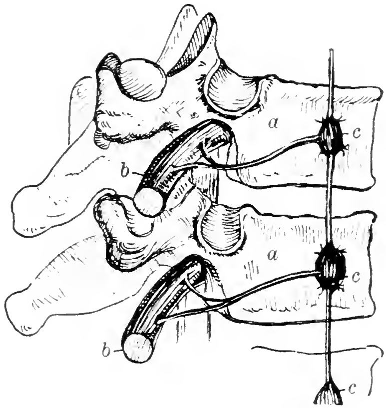


Fig. 134. The vertebræ and the nerves

On each side of each vertebra, *aa*, passing out between the stalks of the arches, are the spinal nerves, *bb*. These nerves connect (1) with the muscles and viscera at corresponding levels, and (2) with the corresponding sympathetic ganglia, *cc*

Bones of animals often persist, buried in the earth, long after the other tissues have completely disappeared. As a result we have remains of animals that lived millions of years ago, and that show many stages between series that are living today. Thus, there are skeleton remains, or **fossils**, of animals that resemble both birds and reptiles. Again, in some animals bones develop during the early stages of growth but never reach the condition of performing any function. This is true of leg bones in the whale, and the legs of certain snakes, which never appear above the surface of the body (see Fig. 132).

The spinal-column units, or **vertebræ** (singular, *vertebra*), are all built on very much the same plan (see Figs. 133 and 134). Among fishes and some of the reptiles there may be an indefinite number of vertebræ, but in the other classes of vertebrates there

is a tendency toward the development of a fixed number. In mammals, for example, there are always seven vertebræ in the **cervical**, or neck, region; the giraffe has no more than a mouse. The thoracic region has twelve vertebræ. The ribs are of varying lengths and make up a sort of cage for the delicate organs in the thoracic cavity (see Fig. 84). They are capable of considerable motion and so permit the breathing movements. In birds the bones tend to fuse together and the ribs are not movable. In man the first seven ribs are attached to the breastbone, or **sternum**, by straps of cartilage. The eighth, ninth, and tenth are connected by cartilage that is attached to the cartilage of the seventh rib. The eleventh and twelfth ribs are not attached in front.

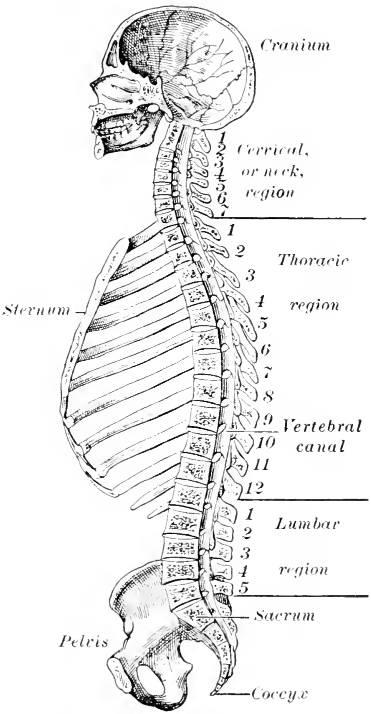


Fig. 135. The human backbone

Each region has a rather definite number of vertebræ. In some of the lower vertebrates (fishes, reptiles) there is considerable variation. The five vertebræ in the sacral region are fused together, and the pelvic girdle is fused to the sacrum. Four or five small vertebræ make up the *coccyx*. In early stages of development there may be as many as eight or nine bones in this "tail" region

In most mammals, reptiles, and fishes the spinal column is nearly straight, or somewhat arched, curving outward on the dorsal side (see Fig. 2). In early stages of human development the column also has the form of a continuous arch from the head to the coccyx; but in adults and in birds it has a more complex curvature (see Fig. 136).

The skeleton of the head region shows many adaptations to the workings of the organism, as well as to external relations. Besides the bony protecting case of the brain we find sockets for the eyeballs and joints for the jaw. The teeth are not bones but special *skin* structures; there are definite sockets in the jaws, however, for all the teeth. The spaces in the face bones are very intricate and are connected with both the sensory and the respiratory functions of the nose. The whole of the hearing apparatus, together with the balancing organ, is inclosed by the bone of the skull (see page 232). There are many openings in the base of the brain box, through which nerves and blood vessels pass. In a saddle-shaped depression in the base of the skull, back of the eyes, lies a two-lobed organ, the *pituitary gland*, which produces important internal secretions (see Fig. 124 and page 178).

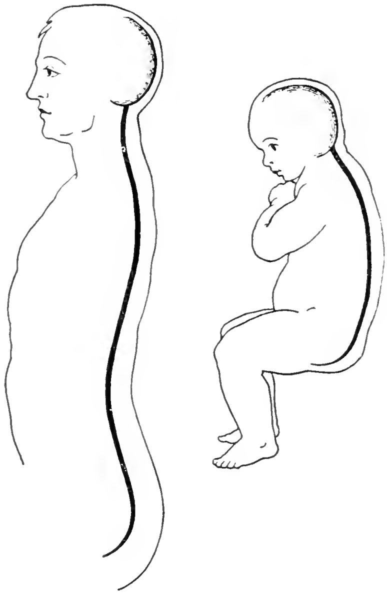


Fig. 136. Development of the erect form

In relation to the upright carriage of human beings, the backbone gradually changes its shape from infancy on. When the erect position is attained the backbone shows four distinct curves

226. The structure and growth of bones. The skeleton of vertebrates differs from the exoskeletons of invertebrates in one very important respect: it is made up of *living tissue*. Bone cells absorb from the lymph a large proportion of mineral matter and deposit this as lime salts outside of themselves (Fig. 137). In the development of the individual from the one-celled stage there appear groups of

cartilage cells at various points. Some of these cartilage centers in time become bones; the cartilage at the ends of certain bones does not become completely *ossified* (that is, changed into bone) until maturity is reached (see Fig. 94). Some cartilage structures never become bony. In some of the lowest fishes the entire skeleton remains permanently cartilage.

The long bones have hollow shafts containing *marrow*. Where two bones move against each other the enlarged ends furnish increased surfaces. Here the bones are spongy on the inside. Thus the skeleton combines mechanical strength with relatively light weight. Among birds the bones are rather more compact but contain larger hollows and are relatively lighter.

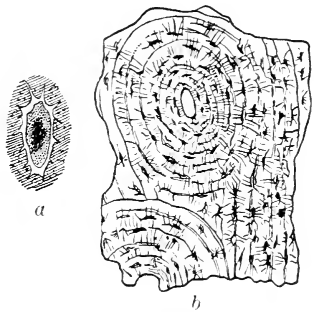


Fig. 137. Growth of bone

Living cells, *a*, deposit lime around themselves but remain connected by tiny canals with one another and with the circulation of lymph, *b*

Through cell division in surface layers, which make up the *periosteum*, the bone grows in thickness; and it is also from these tissues that injuries are repaired by the formation of new bone. Bones increase in length through cell division in special sections between the shaft and the head at each end. As age advances, these growing areas become hardened and further growth is impossible.

The large proportion of cartilage in the skeleton of an infant accounts for the softness and flexibility of the young organism as compared with the adult or aged. With increasing proportions of lime the bones become more brittle. It is accordingly important to prevent pressures and postures in childhood that may lead to distorted or misshapen organs. Primitive peoples used to press the heads of babies out of shape, and some used to squeeze the feet out of shape. Even in comparatively modern times, in Europe, children have been crippled or twisted in order to serve as bait for charity in the business of begging.

227. Development. The transformations observed during the development of insects (metamorphosis, see page 29) are matched by equally great changes in the development of backboned animals. For most of the familiar vertebrates this process is concealed from us because it takes place within the body of the mother or, among birds and reptiles, inside the egg. In fishes and amphibians, however, the stages can be easily seen, as the development takes place in the water (see Fig. 138). Since every individual begins life as a single cell, this stage has been compared to a protozoön. This one cell, or fertilized egg, divides into two; each of these divides again; and so on. For a considerable part of the journey from a one-celled organism to a many-celled organism all the higher species are very much alike (see Fig. 107). When we compare the embryos of several kinds of backboned animals, as the fish, the

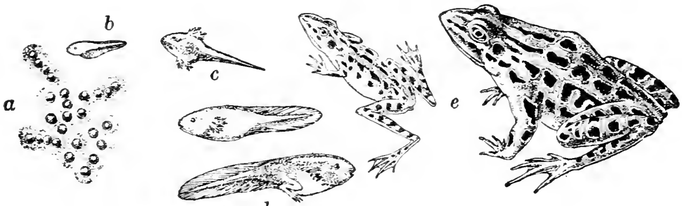


Fig. 138. Development of the frog (*Rana palustris*)

a, eggs; *b*, newly hatched tadpole; *c*, older tadpole with gills and front legs; *d*, tadpole with hind legs; *e*, young adult (gills and tail absorbed) and older mature frog

bird, the salamander, and the rabbit, we find that they are very much alike early in their development, not only when each consists of a single cell but even later, when it is possible to distinguish head and trunk and limbs (see Fig. 139). As they become older they differ from each other more and more. During the development of the human organism after birth the different parts of the body do not grow at the same rate (see Fig. 140). The bones of the skull in the newborn infant do not quite meet at the edges (Fig. 141).

228. Hygiene of the skeleton. The normal growth and development of the skeleton depend upon nutritive conditions during infancy. Defects in the food related to bone formation are of two kinds: (1) improper proportions or quantities of calcium and phosphorus and (2) lack of vitamin A. Normal milk ordinarily yields both the needed minerals and the vitamin A.

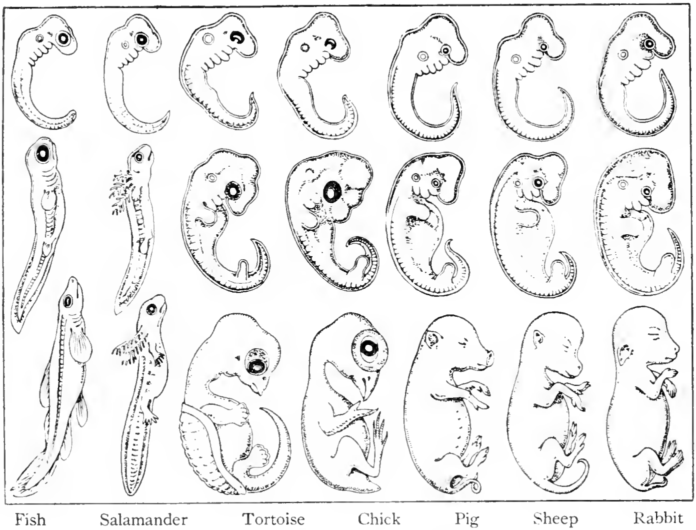


Fig. 139. Parallelism in development of backboned animals

The three rows of embryos represent distinct stages of development. In the first row the stages of the different species are very much alike; in each succeeding stage they are more distinctive

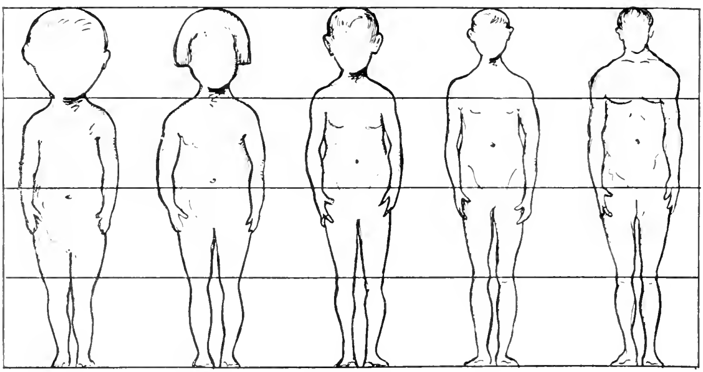


Fig. 140. Metamorphosis in man

A comparison of the infant and the adult shows that after birth the legs of the baby grow more than any other part, whereas the head grows the least. A study of this figure will show other changes that take place in the outward form

although the amount of vitamin in the milk of a mother or of a cow *depends upon the diet of the milk-producer.* It has also been found that cod-liver oil is useful in many cases, because it contains a relatively large amount of vitamin A.[1] But here again a great deal depends upon how the cod-liver oil is prepared, for experiments show that some brands are very effective, while others are almost worthless (see Fig. 142).

Posture may have a direct bearing upon the vital organs: cramping positions interfere with breathing, with the action of the stomach, with the bowels, and, less directly, with the heart, since they may influence the activity of the larger muscles, and so the circulation of the blood (see Fig. 143). Good posture is thus important, not only for the sake of appearance but for the sake of comfort and efficiency.

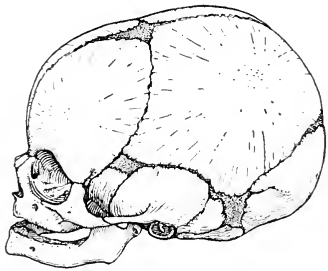


Fig. 141. Incomplete skull of infant

At several points there are rather extensive spaces covered only by skin and connective tissue. As the bones grow at and toward their edges these spaces are gradually filled out

When a bone is broken, new bone cells begin to form from the periosteum, and the space is gradually filled in with solid bone. It is therefore important that the broken ends (1) be *set* together accurately and (2) be *kept* in position until the new formation is strong enough to bear the strains of ordinary activity. In cases of dislocation early replacement is necessary. Caution must be taken against (1) *movements* that may bruise or tear muscles, tendons, or

[1] Experiments on guinea pigs and white rats, as well as observation on young babies, tend to show that the effect of the vitamin A is in many ways identical with the effects of exposure to sunlight. It would seem that the ultra-violet rays (those portions of the sunlight that appear beyond the violet rays in a spectrum) have an important bearing upon the way protoplasm works over lime and that the presence of vitamin A produces similar results. According to some of the experiments it may even be that the ultra-violet rays are somehow "stored" in food and later made active in the body.

ligaments, and (2) prolonged *inaction* that may permit bruised tissues to grow together in an undesirable position.

229. The muscles. The unstriped muscles are controlled automatically by changes in the chemical condition in various parts of the body. The striped muscles, which make up about 40 per cent of the body weight, are controlled by nerves of both the central *cerebrospinal* system and the *autonomic* system.

Fig. 142. The importance of suitable diet

The child in these pictures was suffering from defective nutrition. In the first picture it weighed 14 pounds 4 ounces. The second picture was taken eleven weeks later, after expert treatment, when the child weighed 17 pounds 15 ounces. (Photographs by Dr. Henry Dwight Chapin, at the Speedwell Society)

Thus it comes about that, while these muscles are voluntary in a true enough sense, they also contract and bring about movements which we do not always intend to perform. In breathing, for example, we can hold the breath for a few minutes or increase the rate of breathing; but we cannot hold the breath indefinitely, and we cannot help panting after running, and we cannot help coughing under certain conditions, even though we think we can make a good imitation of a cough when we wish to. While most of us can make our faces produce fair imitations

of expressions that go with various emotions ("register," as the motion-picture people say), most of us cannot help showing in our faces what is happening to our feelings.

Since they constitute so large a portion of the whole body, the muscles influence the whole organism by determining the rate and vigor of many other functions—the circulation of the

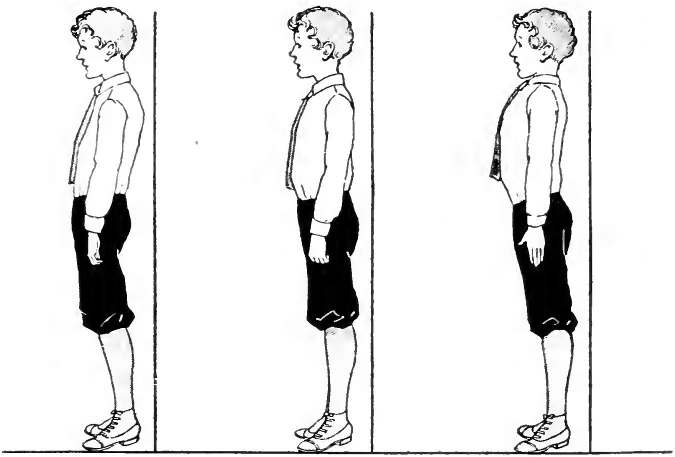


Fig. 143. What is good posture?

It is possible to give you good rules about the position of the neck and chest and back and feet; but these rules are mechanical and treat the human being as you would a machine or an animal that you want to train. Unless you already have bad habits of standing and walking and sitting, the best rule is to take up positions that, in the first place, are free from physical strain and that, in the next place, carry a feeling of confidence, courage, determination, and good cheer

blood, breathing, and the rate at which waste products are eliminated through the skin, the lungs, and the kidneys. Expansions and contractions of the muscles, aside from increasing the demand upon supplies of food and oxygen, bring about mechanical stimulations of the intestines and so promote their well-being. For all these reasons, then, modern man must keep his muscles not only in working condition but actually at work. All our labor-saving devices have made it possible to shift more and

more of the heavy labor to machines, but we cannot shift to any machines or medicines the job of keeping the organism in working condition.

230. Exercise. Many systems of exercise have been developed with the idea of getting what is necessary for the body with the least effort and with the least loss of time. All these systems somehow fail to keep people in good health; at least they fail to keep people following the system long enough to do any permanent good. The fact is that merely moving the muscles is not sufficient. What is needed is a habit of giving the muscles enough work every day to bring out the perspiration, to quicken the breathing, to increase the heart beat. People whose daily work is carried on with the large muscles have this amount of exercise without setting aside any special time or any special thought; but most people who work at desks, or at automatic machines, or at store counters, or at most of the jobs in cities do not get sufficient exercise. They may get tired enough every day, but that is not sufficient to keep the blood coursing through the remotest capillaries, to make the air reach the very last air sacs in the lungs, to clear the blood of all its wastes, to keep the intestinal muscles in condition.

For most people certain outdoor games offer the best and most satisfying substitutes for a variety of interesting work and adventure. For most of us traveling long distances by canoe or on horseback, finding our own food and fuel and preparing our meals and shelter, would be out of the question. Many games, however, have in them very much the same kinds of interests—adventure, rivalry, effort—as real work in the out-of-doors, and they yield similar satisfaction of achievement in addition to the varied exercise. There is real danger, however, that we may overdo these games just because they are interesting; and because they make good spectacles for others there is also the danger that many young people will cultivate stunts and show pieces instead of playing the game for the fun of it. Indeed, there is already so much professional playing of various games that too many people spend what leisure time and spare

money they have in *watching others play* instead of *getting into the games themselves.* That may be good business, but it is not good health, either for the body or for the spirit, when carried too far. For many people dancing is a good form of exercise, because it may be carried on in connection with sociability and the rhythm of music.

Muscular development is a good indication of the general health of the body, but under conditions of modern living we need quick, responsive muscles rather than large, tough ones.

THE HUMAN BODY AND KEEPING IT FIT

1. Knowledge about the structure of the human body
    - Value of such knowledge
        - A frequent subject of discussion
        - Knowledge related to management
        - Common interest in health
    - How such knowledge is obtained
        - Direct observation (external features)
        - Dissections by anatomists
        - Dissection of other animals (in part)
        - Preparations; models; pictures
2. General plan of vertebrate structure
    - Main axis
        - Thorax and abdomen
            - Skeleton
            - Body wall
            - Internal organs
                - Dorsal cavity
                    - Spinal cord
                - Ventral cavity
                    - Lungs (gills)
                    - Heart
                    - Esophagus
                    - (Diaphragm, in mammals only)
                    - Stomach
                    - Intestines
                    - Liver
                    - Pancreas
                    - Kidneys
                    - Bladder
                    - Reproductive organs
                        - Female
                            - Ovary
                            - Oviducts etc.
                        - Male
                            - Spermary
                            - Sperm ducts etc.

Head
  Skeleton (skull and jaw)
  Brain
  Special sense organs
  Eyes; ears; smelling area; taste area; balancing organs
  Mouth
    Connection with food pipe
    Connection with breathing organs
    (Nose)
    Tongue
    Teeth

Appendages
  Number and location
  Characteristic structure
    Skeleton; muscles; covering

3. Structure of frog—a typical amphibian (batrachian)
  General plan
  Characteristics of skin
    Perfectly bald; slimy; pigmentation
  Characteristics of head
    Flat; no neck; protruding eyes
    Nostrils leading into mouth; can be closed
    Wide mouth: tongue; teeth (on upper jaw)
    Eardrums
  Characteristics of limbs
    Adaptations for locomotion: on land; in water
  Internal organs and arrangement
    Digestive organs
      Gullet
      Stomach
      Intestines
      Glands: gastric; liver; pancreas
    Respiratory organs: lungs; bronchial tubes
    Circulatory organs: heart (three chambers); arteries; veins; capillaries (spleen)
    Excretory organs: kidneys; bladder
    Reproductive organs: ovaries with tubes; spermaries with tubes
    Nervous system
      Brain
      Spinal cord and connections
      (Nerve endings in skin, special sense organs, muscles, and viscera)

- Supporting organs
  - Skeleton
    - Bones
    - Ligaments
    - Cartilage
  - Connective tissue
- Motor system
  - Striped muscles of skeleton
  - Striped muscles of heart
  - Unstriped muscles

4. The vertebrate skeleton
   - Comparison with invertebrate skeletons
     - Internal
     - Consists of living tissue (capable of growth and repair)
   - Functions
     - General framework
     - Protection for delicate organs
       - Brain box
       - Eye sockets
       - Thoracic cage
       - Pelvic basket
     - Levers for muscle action (nearly all bones)
   - Composition
     - Bones
     - Ligaments
     - Cartilage
   - Connections of bones
     - Fusions (sacral vertebræ; pelvic bones: pelvis and sacrum)
     - Articulated (all movable joints)
     - Unjointed attachments (pads between vertebræ; cartilages of ribs)
   - Arrangement of parts
     - Main axis
       - Vertebræ
         - Cervical
         - Thoracic
         - Lumbar
         - Sacral
         - Coccygeal ("tail")
       - Ribs
         - (In thoracic region among higher vertebrates)
         - (Indefinite in number among lower vertebrates)
         - (Absent in frog)
       - Sternum

Head
- Skull
  - Brain box
  - Eye sockets
  - Facial bones and nasal passages
  - Internal ear and balancing organs
- Jaw
  - (Teeth)

Girdles and appendages
- Anterior (pectoral) girdle
  - Scapula
  - Clavicle
  - (Coracoid)
- Anterior appendage
  - Humerus
  - Radius and ulna
  - Carpals
  - Metacarpals
  - Phalanges
- Posterior (pelvic) girdle
  - Ilium
  - Ischium
  - Pubis
- Posterior appendage
  - Femur
  - Tibia and fibula
  - Tarsals
  - Metatarsals
  - Phalanges

5. Structure and growth of bones
   - Bone cells
     - Cell division; lime deposits
   - Growing regions
     - Periosteum; growth in length
   - Healing of breaks
6. Development
   - Metamorphosis in frog: egg; tadpole; adult
   - Stages from single cell to embryo
   - Progressive divergence in structure during the development of vertebrates
   - Changes in proportion during development of individual
   - Closing of spaces in brain box
7. Hygiene of the skeleton
   - Nutrition during infancy
     - Calcium and phosphorus
     - Vitamin A; sunshine
   - Strain of overwork and bad posture
   - Danger of deforming bones during childhood
     - Posture; clothing, shoes, etc.
   - Dangers in fractures; in dislocations; in infections
   - Rigidity of spinal column combined with flexibility and elasticity

8. The muscular system
    - Striped muscles
        - Distribution over body
        - Attachment to skeleton (ligaments)
        - Control by cerebrospinal (voluntary) nerves
        - Control (indirectly) by sympathetic nerves
    - Unstriped muscles: in blood vessels; in digestive tract
    - Relation of muscular activity to
        - Breathing
        - Heart action
        - Excretion
        - Digestive processes and elimination
9. Exercise and rest
    - Importance of exercise
        - For the muscles
        - For the viscera
        - For general health
    - Desirable kinds of exercise
        - Use whole body
        - Arouse interest
        - Increase heart action
        - Increase breathing
        - Increase perspiration
    - Importance of rest and sleep

QUESTIONS

1. What is there to show that most people have some concern with health?

2. What methods are there for learning about the structure of the human body?

3. What are vertebrates? How do they differ from other animals?

4. What are the classes of vertebrates? How do they differ from one another?

5. In what ways does the general structure of a frog resemble that of the human body? In what ways do the two differ?

6. How do the structure and the appearance of the frog fit into his way of life?

7. How does a frog get his food? Of what does the food consist? What are some special adaptations of the frog to food-getting?

8. How does the digestive system of the frog resemble that of man? How do the two differ?

9. What drives air into the frog's lungs? What drives it out? What would happen if the frog were forced to keep his mouth closed for a long time? if he were forced to keep it open? Why?

10. How does the breathing system of the frog resemble that of man? How do the two differ?

11. How does the breathing of the frog resemble that of the fish? How do the two differ?

12. How does the breathing of the frog resemble that of the bird? How do the two differ?

13. In what ways is the skeleton of vertebrates like the skeleton of invertebrates? In what ways are they different?

14. How does the heart of the frog resemble that of man? How do they differ?

15. What vertebrates have hearts most like man's? least like man's?

16. In what ways is the mammalian skeleton like that of the frog? In what ways is it different?

17. In what ways is the skeleton of man like that of other mammals? In what ways is it different?

18. What changes take place in the human skeleton during the period of development?

19. What are the particular dangers to the skeleton during infancy? during childhood? during later life? Why?

20. What connections are there between posture and feelings? between posture and health? between health and emotions?

21. Why should we have chairs and desks of different sizes at home, in school, and in offices?

22. What is the use of X-ray machines in treating broken bones?

23. What besides discomfort may result from having one leg longer than the other?

24. What is the advantage of a large muscle development? What is the disadvantage?

25. What connection is there between muscle activity and breathing? between muscle activity and heartbeat? between muscle activity and excretion? between muscle activity and bowel action?

26. How can the activity of the striped muscles influence the unstriped muscles? How can the activity of the smooth muscles influence the striped muscles?

27. How can a state of mind influence the striped muscles? the smooth muscles?

28. What kinds of exercise are good for the blood? for the bones? Why?

29. What are the advantages of real work over drill? What are the disadvantages?

30. What are the advantages of work over games? What are the disadvantages?

31. What are the advantages of watching games over playing them? What are the disadvantages?

32. What connection is there between our clothes and our health?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, chap. ii, The Anatomy of the Human Mechanism; chap. xvii, Muscular Activity.

Cockerell, T. D. A. Zoölogy, chap. xliv, The Structure of Vertebrates.

Keith, Arthur. The Engines of the Human Body, "How Muscles Operate" (extract in C. H. Ward's "Exploring Nature," pp. 198–208).

United States Bureau of Fisheries. Report for 1919, Appendix 6, Frogs, their Natural History and Utilization.

Public Health Reprint 779, Posture of School Children.

United States Department of Agriculture, Bureau of Chemistry. *Bulletin 126*, The Harmful Effects of Acetanilid, etc.

MAN'S DEPENDENCE

There is much that each one of us can do to keep his body fit for work and play and for the enjoyment of life, and it is important for us to get certain habits and attitudes that will preserve the health of the body. But beyond a certain point we cannot keep healthy alone. There are other people and other species of living things to consider. We depend upon others both for our material needs and for our happiness and comfort. A large part certainly of what is called spiritual welfare means healthy relations to other people. But the physical welfare of the body is constantly influenced by the doings of other human beings and other organisms, plants as well as animals. We must consider how we may control this outside world for human health.

CONTROL OF THE ENVIRONMENT FOR HEALTH

CHAPTER XXIX

HOW DISEASES ARE CAUSED

Questions. 1. Can anything in food make people sick? 2. Can anything in the air or water make people sick? 3. Can the lack of anything in food, air, or water make people sick? 4. Can things get into the body in other ways than through the food, air, and water, and make people sick? 5. In what ways can living things be injurious to other species of organisms? 6. How can injuries to organisms be remedied? How can they be prevented? 7. Why must there be sickness?

231. The food relation between organisms. We know now (1) that every living thing must have food; (2) that chlorophyl-bearing organisms are the only ones that can manufacture food out of inorganic raw material; and (3) that all other organisms must supply their needs from the bodies of such food producers. These dependent species, in many cases, get their food from the bodies of plants and animals that are already *dead*. Thus, molds (fungi) of many kinds are found on dead plants and animals, as well as on organic materials artificially worked up—bread, cheese, leather, and so on. Other species of fungi are mildews and mushrooms; the former are found growing on cloth, the latter on cut timber or railroad ties. Many insects and worms live upon all sorts of dead organic matter, from the carrion beetle and clothes moth to the common earthworm. Then there are the myriads of protozoa and bacteria living in the soil and in all natural waters, using dead organic material as food.

Most of the familiar animals and a number of plants attack *living* things and destroy them for their own food. The gentle

cow and the soft-eyed deer browse on the herbage and are direct destroyers of living things. Many of the **predatory** animals, those that catch their prey, are in turn exposed to predatory enemies: a frog catches a worm and is devoured by a snake; a bird eats an insect and is then killed and eaten by a cat; and so on.

A third means of obtaining food is to take it directly from the body of a living organism without necessarily killing the organism. In this way there are fungi living on the bodies of almost every species of green plant. There are many species of protozoa, worms, and other classes of animals living on the bodies of almost every species of vertebrate. Plants and animals that get their food in this way are called **parasites**.

We sometimes find an association of two species that appears to be a parasitic one (that is, of one organism living upon and at the expense of another), but in which the relation is really different. For example, on the roots of plants in the bean family (clover, peas, vetches, lupines, etc.) are found little swellings, or tubercles, containing millions of bacteria. These bacteria live by using some of the food material in the cells of the roots. So far, then, they appear to be parasites. But a closer examination shows that these bacteria absorb and combine nitrogen from the atmosphere, and so supply the host with material for protein-making. There is thus an exchange of materials or services, and such a relationship is one of **mutualism** (see Fig. 144).[1] Certain species of ants may be seen to "milk" plant lice by stroking them with the antennæ and feeding upon the secreted juices; but, on the other hand, the ants are said to protect the plant lice from other enemies, and thus to give something in return for the food which they obtain. There are many other cases of mutualism between different species.

232. Parasite and host. The plant or animal upon which or in which another organism finds its food is called the **host.**

[1] After a crop of clover has been grown on a piece of land, the soil will contain more nitrogen than it did at the beginning of the season. Accordingly the plants of the bean family not only contain a larger proportion of nitrogenous compounds (proteins) than most other plants, but are of special value in the *rotation of crops*. After a series of grain or root crops, for example, have been removed from a piece of land, a season or two of a leguminous crop will restore the removed nitrogen to the soil.

There are many kinds and degrees of parasitism. The dodder, a plant of the morning-glory family, often grows as a climbing vine on various common shrubs. It digs its roots into the stem of the host and absorbs from it organic food as well as water and salts. When the dodder is deprived of food, however, it is capable of forming chlorophyl and leading an independent life. In other words, some parasites are such whenever they have a chance to be and are independent organisms when they must get food more actively. The mistletoe, another parasite that lives on branches of trees, produces chlorophyl and depends upon the host only for water and salts.

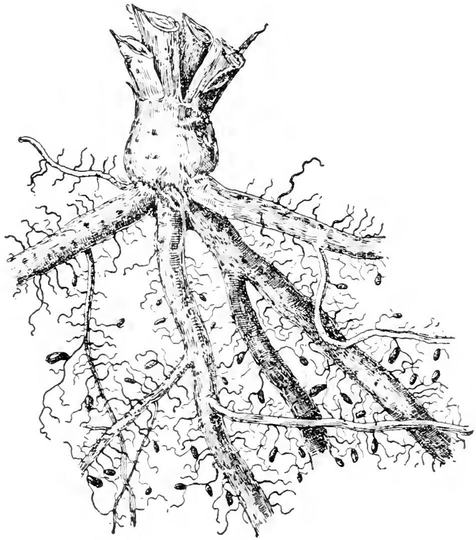


Fig. 144. Tubercles on the roots of red clover

The swellings are inhabited by a vast number of tiny one-celled organisms that feed upon carbohydrates produced by the clover plant. These guests absorb nitrogen from the air and combine it with material taken from the host, producing proteins. The clover plant makes use of the excess of protein. There is thus a partnership in which both members benefit

The common mosquito, of which there are several species living in our country, catches tiny water plants and animals during its early stages; but after reaching the adult stage the female mosquito is a parasite in that she draws upon the juices of larger organisms for food. Thus we see different degrees of food parasitism: there are what we may call (1) *compulsory* as against *optional* parasitism; (2) *complete* as against *partial* parasitism; and (3) *permanent* as against *temporary* parasitism.

From the point of view of the host there are also degrees. In some cases the parasite helps himself to a small quantity of material that is hardly missed; in other cases the amount of damage done may be serious or even fatal. It is in these cases that we come to the problem of how diseases are caused.

The European cuckoo will lay her eggs in the nests of strange birds, thus getting from other organisms at least two direct benefits — the work of building a shelter for the young and the work of keeping eggs warm during incubation. There is also the feeding of the young by the strange foster mother. This is a case of getting *services* from another organism without giving anything in return. It is in this sense that we use the word *parasitism* in connection with higher animals, and especially in connection with human affairs.

233. Injury done by parasites. The simplest relation between a parasite and its host is that in which the parasite takes for its own use materials accumulated or produced by the host. The tapeworm (see Fig. 156) lives in the intestine of a human being or some other mammal and absorbs digested food through its own body wall. It rarely deprives the host of enough nourishment to cause him serious injury. Very rarely is an oak tree sufficiently injured by the mistletoe to show bad effects, and the flea or the mosquito takes so little blood that we rarely miss it.[1] The digestive tract of every animal that has one is likely to be inhabited by various species of protozoa, bacteria, and minute worms; in most cases the food which these inhabitants withdraw is not sufficient in amount to cause any privation to the host. The hookworm, however, attaches itself to the lining of the intestine and feeds upon the rich materials manufactured by its host. This is a serious privation, and those who suffer from hookworm disease show loss of energy and initiative, in some cases to a fatal degree (see page 334).

Many parasites, possibly all, give off peculiar substances that result from their metabolism, just as do our own tissues. In

[1] The bites or stings of insects are often more serious than the removal of blood, as we shall see later (Chap. XXXI).

some cases certain of the substances thus excreted are poisonous to the host. In this way the host may be made seriously ill or even be killed by the poison. Diseases known to be of this kind in man number between thirty and forty, and it is possible that still other ailments may be due to such poisoning. The parasites causing such disturbances may be plants (mostly bacteria) or they may be animals (chiefly protozoa). Among the

Fig. 145. The effects of a plant parasite

A healthy cotton plant and one attacked by *wilt*, a diseased condition due to the action of a microscopic parasite related to the molds. (From Duggar's "Fungous Diseases of Plants")

diseases caused in this way by bacteria are diphtheria, typhoid fever, and tetanus, or lockjaw. Among the diseases caused in this way by parasitic protozoa are malaria, dysentery, and sleeping sickness.

A third effect that parasites may produce upon the host is that of destroying special tissues or organs by using the material as food (see Fig. 145). The name *consumption*, which was formerly very common for tuberculosis of the lungs, tells this story strikingly. Parasites that injure chiefly by destroying tissues may also give off poisons to some degree, and vice versa.

The activities of a parasite may cause injury to some particular organ and interfere with its functions so much as to affect the health of the whole body. Pneumonia, rheumatism of the heart, and cerebrospinal meningitis are examples of diseases in which the parasite causes local injury. When the injury to one of these vital organs goes too far, death results.

234. Other classes of disease. Certain bacteria cause decay of food material; with the production of poisonous wastes; anybody taking food that has undergone such changes will be taking the poison into his system directly. Most important for human beings are the inorganic poisons lead, mercury, and phosphorus, which are used in certain industries. In recent years the use of white phosphorus in the manufacture of matches has been completely discontinued because of the serious injuries which the fumes produced upon workers.

A deficiency of essential elements or an excess of materials may bring about abnormal behavior on the part of various organs. Nutrition may also affect the activities of the ductless glands, and so bring about derangement in the workings of the essential organs. Among the nutritional diseases are rickets (see Fig. 142), beriberi, pellagra, and scurvy. Deficiencies of the thyroid, showing themselves in goiter and disturbances of the nervous system, have been traced to a lack of *iodin* in the food or water.

235. Symptoms and causes. For many centuries people knew nothing about disease except the suffering of the patient and the outward manifestations. A sickness meant pains in various parts of the body, and changes in the color of the skin, outbreaks on the skin, fever or chills, sweating or dryness, perhaps a peculiar odor, looseness of the bowels or constipation, and so on. The object of treating or drugging was to get rid of the symptoms: if a person was hot, he had to be cooled; if he was cold, he had to be warmed; if he was dry, he must have water. During the latter part of the nineteenth century the art and the science of medicine were completely revolutionized through the discoveries made by the French investigator Louis Pasteur

(1822–1895) and others as to the relation between microbes and disease. For the first time we knew exactly how certain particular diseases were caused, and with this knowledge it has become possible in many cases to *cure* with greater certainty than ever. But what is more important, we are now able systematically to *prevent* diseases that formerly destroyed millions of people.

HOW DISEASES ARE CAUSED

1. Food relations of organisms
    - Independent organisms (chlorophyl bearers)
    - Organisms living on dead organic materials
    - Organisms killing others for food (*predatory*)
    - Organisms living at the expense of other organisms (*parasites*)
        - Complete or partial parasitism
        - Permanent or temporary parasitism
        - Obligatory or optional parasitism
    - Organisms exchanging materials or services with other organisms (*mutualism*)
2. Effects of parasites upon hosts
    - Withdrawing material
    - Poisoning with by-products
    - Destroying tissues
3. How organisms may become diseased
    - Injuries caused by parasites
    - Poisons
        - Spoiled food
        - Unsuitable material used as food
        - Inorganic poisons
            - Lead
            - Mercury
            - Copper
            - Phosphorus
    - Nutritional deficiencies
        - Vitamin A (rickets)
        - Vitamin B (beriberi)
        - Vitamin C (scurvy)
        - Iodin (goiter)
    - Unknown causes
        - Cancer
        - Diabetes
        - Bright's disease
4. Effects of disease (*symptoms*)
    - Excessive activity in some organs or tissues
    - Deficient activity in some organs or tissues
    - Destruction of some tissues or organs
    - Pains and discomforts
    - Chemical changes in various fluids of the body

QUESTIONS

1. What kinds of living things can be entirely independent of other organisms? Why?

2. What kinds of organisms must be dependent upon others? Why?

3. In what ways can living things be of use to other species?

4. Why cannot all living things be entirely independent of others?

5. Why cannot all living things prey upon others?

6. Why cannot all living things be parasites?

7. In what ways can parasites cause injury to living things?

8. How can parasites be of service to other species? to the host?

9. Could people live indefinitely on an artificial island without plants? If so, would they be independent of plant life?

10. What should you consider the food relation between man and sheep? Why? Between the bee and the clover plant? Why? Between man and the cow? Why?

11. Why are there more parasites among microbes than there are among larger plants and animals?

12. Why are larger plants and animals more exposed to parasites than smaller ones?

13. Why is it important to distinguish between symptoms and causes of disease? Why is it important to know both the symptoms and the causes of diseases?

REFERENCE READINGS

Conn, H. W. Bacteria, Yeasts, and Molds in the Home, chap. xiv, Disease Bacteria.

Hough and Sedgwick. The Human Mechanism, chap. xxxi, Communicable Diseases.

Cockerell, T. D. A. Zoölogy, chap. xxvi, Protozoa and Disease; chap. lix, Louis Pasteur.

Supplement 30, Public Health Reports, Description of Common Colds.

Farmers' Bulletin 1330, Parasites and Diseases of Sheep.

Farmers' Bulletin 1337, Diseases of Poultry.

Farmers' Bulletin 781, Tuberculosis of Hogs.

United States Bureau of Fisheries. Report for 1918, Appendix 5, The Flatworm as an Enemy of Oysters.

Public Health Reprint 811, Louis Pasteur.

CHAPTER XXX

MICROBES AND THEIR CONTROL

Questions. 1. Of what use are microbes? 2. Can we make them increase in numbers if we wish to? How? 3. How can we make them diminish in numbers? 4. How do microbes cause disease? 5. How are diseases carried? 6. How can we keep microbes from causing disease? 7. How can we keep diseases from spreading? 8. How can we find out under what conditions bacteria thrive and under what conditions they die out? 9. How can we tell whether a method of treating microbes produces the results that we wish?

236. Bacteria. One-celled plants and one-celled animals are sometimes spoken of collectively as **microbes**, which means *small living* things. Occasionally one hears the name *germs* applied to the microbes that are known to cause disease. *Germ* suggests something out of which life can develop. We have the same expression applied to the embryo of a seed (see page 67), and to the reproductive cells of plants and animals (p. 512, Chap. XLIII). Germs of disease are structures, or bodies, that have been found by strict experimentation to give rise to more like themselves, and to bring about a diseased condition in the organism in which they live.

Bacteria are among the simplest plants. Each individual (*bacterium*) consists of a single cell, with fairly distinct cell wall but lacking chlorophyl. There are three main groups of bacteria, classified according to the general form of the cell. The **bacilli**, or rod-shaped bacteria, include those that cause tuberculosis, typhoid, and diphtheria. The **cocci** (*kŏk'sī*), or ball-shaped bacteria, include those that cause pneumonia and pus. The **spirilla**, or spiral-shaped bacteria, include those that cause relapsing fever (see Fig. 146).

The bacteria have no special organs for receiving food, and the cell wall permits no solid particles to come through, as is

the case in the ameba. In the presence of water, however, they are able to make use of solid food by first secreting a digestive ferment, or enzym, which liquefies the organic matter, and then absorbing the digested material (see Fig. 73). Air is absorbed through the moist membrane, and carbon dioxid and other wastes resulting from metabolism are excreted by diffusion through the cell wall. Material taken in is assimilated and the

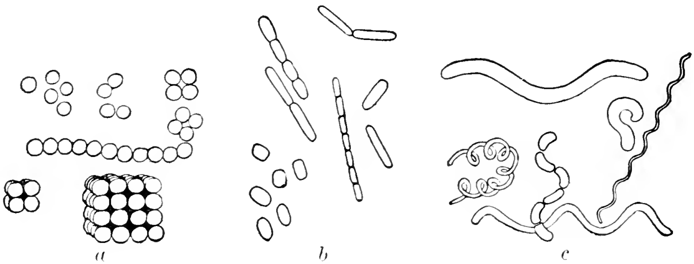


Fig. 146. Types of bacteria

There are three main groups of bacteria, classified according to the general form or shape of the cell: *a*, round-celled, or *coccus*, type (plural, *cocci*, pronounced *kôk'sī*); in some species the cells scatter; in some they cling together in clumps; in others they cling together in chains. *b*, rod-shaped type, or *bacilli*; in some the length is barely greater than the thickness; in other species the cell is several times as long as it is thick. *c*, the spiral type, or *spirilla*; in some this is hardly more than a rod with two or three bends; in other species it has a rather definite corkscrew appearance

cell grows. After reaching a certain size the cell divides into two by a rather simple process of splitting through the middle crosswise. Bacteria of one kind or another will grow wherever there is organic matter, moisture, and not too low or too high a temperature. They are destroyed by sunshine, by various chemicals, and by the temperature of boiling water; in many species a much lower temperature is fatal. When the temperature gets too low, the metabolism of bacteria will be suspended, but as a rule they cannot be destroyed by freezing.

Like many other organisms, bacteria that are frozen can resume their activities on being thawed out again, provided the change is not too rapid. Apparently freezing has the same effect as drying, since it locks

the water molecules up tight, so that there is no movement of water or salts. High temperatures, on the other hand, bring about a change in the proteins (compare boiling white of egg) that is not reversed when the temperature is lowered again. You can unfreeze ice, but you cannot uncoagulate the hardened white of egg or make it liquid again.

237. Animal microbes. The protozoa, as we have seen, are the simplest of animals. Like the bacteria, they consist of one-celled organisms. The ameba, which swims about freely in water and finds its food in smaller organisms and bits of dead organisms (see page 59), has many relatives that are parasitic on man or other animals. Malaria, dysentery, African sleeping sickness, tick fever in cattle, and other diseases in man and the lower animals are caused by different species of protozoa. Many of these simple animals go into a resting stage, and in some there are several distinct stages in the complete life history. A very striking fact in the life history of these animals is that one stage is passed in one host, while another stage is passed in a totally different host. The same fact has been observed in the life of other parasitic animals, as the tapeworm, the liver fluke, and the trichina; and this is also true of many parasitic plants, as the wheat rust, one variety of which spends part of the cycle on the wheat and part on the barberry plant. This fact led to a great deal of confusion when scientists first attempted to make a complete study of any of these species; but in the end it turned out to be of great help in our struggle to overcome these parasites, as we shall see later.

238. Useful microbes. Since bacteria bring about the decay of dead plants and animals, they return to the soil materials that can again be used by plants and eventually become animal protoplasm. Some bacteria, because of their mutual relations to plants of the bean family, may add to our supplies of protein food (p. 301). The bacteria themselves, feeding upon dead organic remains, are in turn eaten by various protozoa and other minute animals; these are then eaten by larger animals, and so on until we get to forms that are large enough to serve as food for man, as shrimps, clams, fish, etc. Still further uses

of bacteria are found in various industrial applications and in the disposal of sewage (see page 431).

239. Communicable diseases. Before bacteria can cause disease they must enter the body of the host. Ordinarily they cannot get through the skin. The *infection*, or entrance into the body, takes place (1) through a cut or break in the skin or (2) through one of the regular openings to the interior of the body, as the mouth or nose.

Since the time of Pasteur many physicians and biologists have succeeded in finding the particular species of parasites connected with some of the most important diseases of man, such as tuberculosis, diphtheria, typhoid fever, tetanus, cerebrospinal meningitis, and influenza. The methods worked out have been used successfully in *preventing* the spread of many other diseases, although the specific organisms that cause the diseases are not known, for in addition to discovering that a specific disease is caused only by a particular species of parasite (for example, typhoid fever is caused only by the typhoid bacillus, and so on), we have found (1) that the parasites leave the host in special ways; (2) that they are commonly transferred to other hosts in special ways; and (3) that they enter the bodies of new hosts in special ways.

The table on the opposite page tells how the germs of a number of common diseases are thrown off from their host, how they are carried about, and how they enter the bodies of new hosts.

There are three different points at which we might plan to prevent the spread of the diseases mentioned:

1. *At the point of leaving the first host.* This would mean, if not preventing the bacteria from getting out, at least protecting discharges from the body, and objects that come in contact with the host or with these discharges, and perhaps killing the parasites at this point.

2. *In the course of transmission.* This has to do with the objects that come in contact with the sick person and with the discharges. The air which separates people cannot very well be eliminated, but, like the other objects and materials that

TRANSMISSION OF COMMUNICABLE DISEASES

Disease	How Germs Come out	How Germs are Carried	How Germs Enter
Chicken pox	Mouth and nose spray	Air	Nose and mouth
Diphtheria	Mouth and nose spray; saliva	Air, objects exposed to spray or saliva	Nose and mouth
German measles	Mouth and nose spray	Air	Nose and mouth
Measles	Mouth and nose spray	Air	Nose and mouth
Mumps	Mouth and nose spray; saliva	Air, objects exposed to spray or saliva	Nose and mouth
Scarlet fever	Mouth and nose spray; saliva	Air, objects exposed to spray or saliva	Nose and mouth
Septic sore throat	Mouth and nose spray; saliva	Air, objects exposed to spray or saliva	Nose and mouth
Smallpox	Mouth and nose spray	Air	Nose and mouth
Tetanus (lockjaw)	Contact	Hands or objects	Breaks in skin
Trachoma	Contact	Hands, towels, etc.	Contact with eyes
Tuberculosis	Mouth and nose spray; milk	Hands, objects, etc.	Nose and mouth, food
Typhoid fever	Mouth, excretions, intestinal waste, and occasionally through skin	Hands, various objects, flies	Food
Whooping cough	Mouth and nose spray	Air	Nose and mouth

touch now one person and now another, it might be freed of dangerous inhabitants, floating about as dust.

3. *At the points of entry into the body.* This would mean guarding the nose, the mouth, the eyes, and the skin generally, and the avoidance of contact with food or anything else that might be contaminated.

In a general way all these methods are used. Discharges from sick people are sterilized (that is, poisoned so as to kill the bacteria) or burned; utensils and clothing are sterilized by fumigation or otherwise, or burned; and entry of bacteria is prevented. That these methods are actually effective is indicated by *the steady decline in the prevalence of various communicable diseases* (see Fig. 147).

240. Individual protection. The most general means of preventing infection is through the protection of our food and drink from contamination. This means that we must take pains to protect fresh food from dust, from the mouth spray or nose spray of people or other animals, and from contact with unclean hands, containers, or other objects. Each of us can at least clean his own hands before every meal, avoid the use of cups and towels that have been used by others since the last cleaning, sterilize a cut or wound (see page 188) on his own skin, and avoid food that has been unduly exposed. On the other hand, we can avoid endangering others by refraining from spitting where the bacteria in the spit will have a chance to be scattered; we can cough or sneeze into our own handkerchiefs instead of into the air; we can keep our hands off food or other objects that are to be used by other people. But we shall find that, no matter how particular we are about protecting our own skins, so to speak, we shall always be exposed to the ignorance or carelessness of other people, and no matter how thoughtful or considerate we are individually, there are many details that we simply cannot look after ourselves. For these reasons it becomes necessary to establish sound methods of carrying on the routine work of certain classes of people, as well as to establish regulations for all of us. Finally, it is necessary for special work to be done by people who are especially appointed for it, because it is impossible for each individual to do his part. This is true, for example, in protecting a city's water supply or in exterminating the mosquitoes of a region (see Chapters XXXIV, XXXVI, etc.).

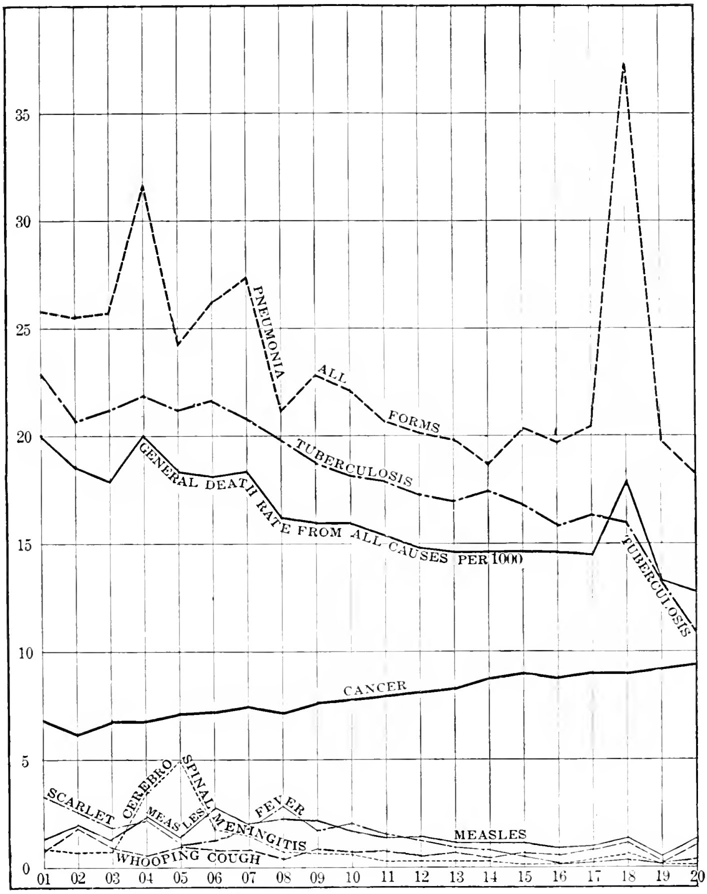


Fig. 147. Mortality rates for various diseases

In the early part of the period the fluctuations are irregular; in the latter part the infectious diseases show a steady decline. There is a steady decrease in the general death rate, and a steady increase in the death rate from cancer. The figures on the left indicate the number of deaths per 10,000 of population in New York City; the figures at the bottom are for the years. The general death rate is on a scale showing the deaths per 1000 for each year. The high point for pneumonias in 1918 represents the influenza epidemic

MICROBES AND THEIR CONTROL

1. Microbes (small living things)
    - Kinds
        - Plant microbes
            - Bacteria
                - Bacilli (rod-shaped)
                - Cocci (berry-shaped)
                - Spirilla (spiral-shaped)
        - Animal microbes
            - Protozoa
    - Relation to human affairs
        - Useful
            - Return organic matter to soil and water
            - Part of food series from lowest to highest forms of life
            - Contribute to make air nitrogen usable
        - Injurious
            - Spoil food and other organic matter
            - Cause illness in man and other organisms
            - Kill human beings and other organisms
2. How bacteria live
    - Food-getting
        - External digestion; absorption
        - Assimilation and growth
        - Respiration through cell wall
        - Excretion through cell wall
        - Reproduction
            - Simple cell division
            - (Spores formed in some species)
3. Relation of environment to life of bacteria
    - Conditions favorable
        - Presence of organic matter (food)
        - Moisture
        - Moderate temperature
        - (Darkness)
    - Conditions unfavorable
        - Dryness
        - Extreme cold (not fatal)
        - High temperature
        - Sunlight
        - Chemical poisons

4. How bacteria get into the body
    - Breaks in the skin
    - Normal openings
        - Mouth (food, drink, foreign bodies)
        - Nose and lungs (air breathed, dust)
        - (Eyes) (dust ; soiled fingers)
        - (Ears)
        - (Urethra)
5. Transmission of disease germs
    - Critical points
        - Discharge from host
        - Transfer by air, or otherwise, to second host
        - Entrance into body of second host
        - (Multiplication in host)
    - Carriers
        - Spit
        - Spray
        - Dust (air)
        - Contact
        - Handkerchiefs, towels, utensils, etc.
        - Food
        - Water
        - Insects
        - (Dogs, cats, etc.)
6. What the individual can do
    - To protect himself
        - Avoid taking into the mouth water, food, etc. that may have been exposed to infection
        - Maintain personal cleanliness (for example, wash hands before every meal)
        - Avoid use of common towel, cup, etc.
        - Disinfect cuts, wounds, etc. promptly
        - Avoid contacts with known or suspected cases of infectious illness
    - To protect others
        - Avoid spitting where germs may be carried away
        - Cover face when coughing, sneezing, etc.
        - Avoid touching food, dishes, etc. to be used by others.
        - Protect food, water, etc. from dust.
        - Coöperate with home and community in maintaining sanitary conditions

QUESTIONS

1. What is the advantage of using poisons for killing bacteria? What is the disadvantage?

2. What are the advantages of refrigeration (low temperature) for storing food? What are the disadvantages?

3. Why is boiled water safer to drink than raw water? What are the disadvantages of using boiled water?

4. Why are sick people quarantined? How long should a sick person be quarantined? Why?

5. What is the best point at which to fight an epidemic? Why?

6. How can we preserve our own health without depending upon others?

7. How can we become liable for the health of others?

8. How can we measure the value of different methods of combating disease?

9. How can we prove that diseases are due to microbes rather than to some other conditions, such as fear, bad weather, or "evil eye"?

REFERENCE READINGS

Conn, H. W. Bacteria, Yeasts, and Molds in the Home, chap. viii, The General Nature of Bacteria; various chapters for special reports.

Hough and Sedgwick. The Human Mechanism, chap. xxi, Prevention and Cure of Colds and Some Other Inflammations.

Ward, C. H. Exploring Nature, "Bacteria," pp. 209–219; "Tuberculosis," pp. 220–230.

Farmers' Bulletin 440, Bacteria in Milk.

United States Department of Agriculture. *Bulletin 342*, Present Status of Pasteurization of Milk.

Bureau of Animal Industry. *Bulletin 161*, Study of Bacteria which survive Pasteurization.

Farmers' Bulletin 926, Some Common Disinfectants.

CHAPTER XXXI

INSECTS IN RELATION TO DISEASE

Questions. **1.** How can insects cause disease? **2.** What kinds of diseases are caused by insects? **3.** What kinds of insects are most dangerous? **4.** How can we tell that diseases are caused by insects and not merely by the conditions in which they live—for example, hot weather or bad night air? **5.** How can we best keep insects from causing disease? **6.** Is it right to destroy flies and other animals?

241. Insects eat. Insects concern us chiefly as *eaters*. They may eat materials that are of value to us, or they may prey upon plants and animals that are of use to us; and, like most other animals, we are ourselves exposed to the attack of insects in search of food. Many species of fleas and lice, of bedbugs and horseflies, of midges, black flies, and mosquitoes, have made themselves obnoxious to man by sucking his blood, by causing more or less serious irritations of the skin, and, as we have discovered in recent times, by infecting him with microbes capable of causing more serious injury.

242. Insects move about. As carriers of disease, insects are related to us in two different ways. The first is illustrated by the common house fly, lately called the *typhoid fly*. This animal has been shown to carry various bacteria, protozoa, and the eggs of parasitic worms on its legs and proboscis, and it leaves these germs where they have a good chance of entering the body of some human being. The female lays her eggs in horse manure; but where there is no horse manure, she will use cow, sheep, pig, or chicken manure, or decaying fruit, fish, meat, or vegetables (ordinary garbage, for example), or any mass of decaying organic matter. The adult fly will visit, for feeding, not only such materials but all kinds of perfectly good food that may be exposed in groceries, meat shops, kitchens, dining rooms,

restaurants, or picnic grounds. Flies will visit open wounds or sores on the bodies of animals, and they will visit the excrements of man and other animals; and then they will regurgitate, or cast back, the contents of the crop upon some dry food, like sugar, thus transferring some of their earlier intake. We can see, then, what excellent opportunities this animal has not only to collect a varied assortment of bacteria but also to distribute them widely.

From a report made by an army commission as to the causes of epidemic fevers in the army camps during the Spanish-American War we learn that "flies swarmed over infected fecal matter in the pits and fed upon the food prepared for the soldiers in the mess tents. In some instances where lime had recently been sprinkled over the contents of the pits, flies with their feet whitened with lime were seen walking over the food." We can readily understand why it was that more soldiers were killed by intestinal diseases than by Spanish bullets.

243. Fighting flies. Just as soon as we realize the relations of the house fly to mankind we are tempted to "swat" every fly we see; but if we all swatted flies, and did only that, the fly pest would hardly receive a serious check, for the insect breeds faster than you and I can kill the progeny, and there is nothing to prevent the flies raised in the stable down the street from coming into our yard.

We have to attack the insects before they are old enough to fly about; that is, *we must prevent their breeding* by removing, destroying, screening thoroughly, or poisoning all materials that may serve as food for the maggots. The struggle between man and the fly is not that of a particular person against a particular fly, but of one species against another, and we must carry on our end of the fight through community or group action. Better than *swatting* the fly is the complete elimination of the tribe from all places inhabited by human beings.

On the farm or in a village stable manure can be profitably spread out upon the ground, in field or garden, every day or two. The manure will then dry quickly and the sunlight will kill eggs and maggots. In larger towns and cities it should not

be difficult to organize the removal of manure and garbage at a comparatively low cost, since the manure is worth gathering for fertilizer and the garbage has a decided commercial value. Where the amount of garbage or manure accumulated is so

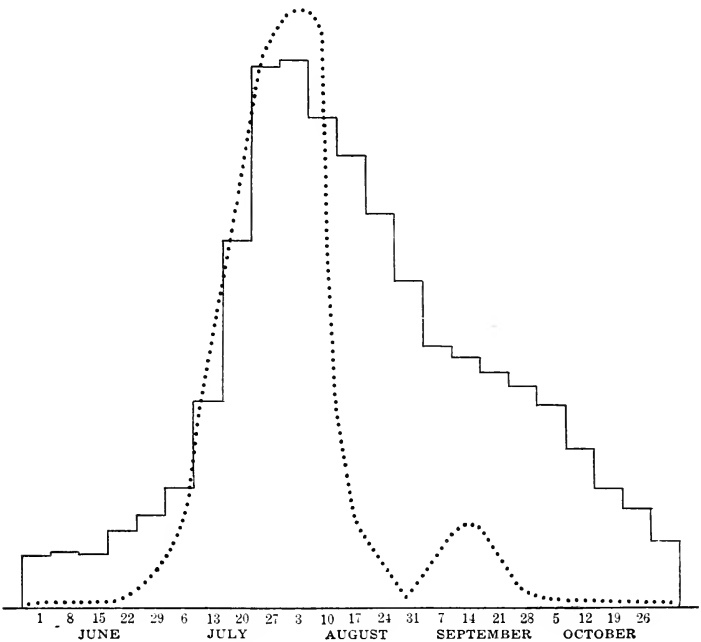


Fig. 148. Flies and intestinal diseases

In New York City a careful study was made (1907–1908) to find the relation between the prevalence of flies and the amount of typhoid fever. The height of the dotted line corresponds to the number of flies caught in traps, week by week, from the beginning of June to the end of October. The solid line corresponds to the number of people who died from intestinal diseases during the same period in the same districts of the city. Typhoid is most frequent where and when flies are most abundant, and there is a direct relation between the insects and the distribution of the disease

small that its removal is relatively expensive, it should be screened so that flies cannot reach it; but screening is very expensive and seldom altogether satisfactory. It has been found most effective to provide for the systematic removal of garbage

and stable manure at least once a week,[1] and to keep streets, back yards, markets, and kitchens perfectly clean (Fig. 149).

Lime, crude oil, copper sulfate, formaldehyde, and other poisonous substances have been used in treating garbage and manure to prevent the breeding of flies; but such treatment is generally undesirable because it makes the manure and garbage worthless for use as fertilizer. Borax and hellebore can be used so as not to injure the manure.

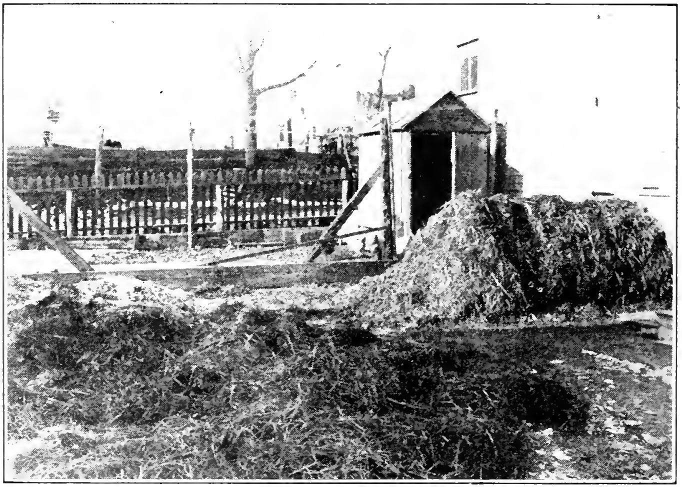


Fig. 149. A breeding place for house flies

The community that saves itself money or trouble by permitting back yards of this kind usually pays for its economy and indifference with disease and death. With the economies of motor cars and traction engines must be reckoned the reduction in typhoid fever and other fly-borne diseases

Until a community succeeds in eliminating the flies it is well for every household to protect its own food supply by suitable screening of the house and by special care in regard to the exposure of food. Every purchaser of food can help by systematically refusing to patronize dealers whose premises harbor flies, and we can all help by keeping our own premises clean and free from these insects (Figs. 150, 151).

[1] The life history of the fly covers a period of ten days.

Fig. 150. Food exposed to the visits of flies

Fig. 151. Food protected from flies

Many food dealers have gone to the expense of installing equipment to protect their customers from the danger of contaminated food. Whether the dealer can afford to do this or not, the public cannot afford to leave its food exposed

244. Intermediate hosts. Of all the diseases from which man has suffered malaria is said to be the most widespread, occurring all around the earth as far north and as far south of the equator as mosquitoes can be found.[1] The disease is caused by any one of three or four species of protozoa related to the ameba and known as the *plasmodium* of malaria. The animal feeds upon the red corpuscles of the blood of its host and then *sporulates*, that is, breaks up into a large number of tiny bits of protoplasm called **spores**. Each spore is capable of resuming life activities under suitable conditions. The spores enter new corpuscles, and the process is repeated indefinitely, greatly weakening the victim and sometimes killing him (see *a* to *e*, Fig. 152).

The French scientist Alphonse Laveran, working in Algeria, succeeded in infecting volunteers with the blood of sick people, but he could not find out how the infection takes place naturally. It took twenty years of careful research and experimentation to establish the fact that mosquitoes of the genus *Anopheles* are the agents of infection. In 1900 an elaborate experiment was conducted by scientists coöperating in England and Italy. In this experiment a number of volunteers lived in the badly malarious Roman Campagna in houses that were carefully screened against the entrance of mosquitoes. They were also careful not to go out in the evening (when *Anopheles* is about) without wearing veils and gloves. Thus they lived through the most dangerous part of the year, from early in July until late in October, *and not one became sick, although many of their neighbors became infected with malaria during the summer.* At the same time some mosquitoes were caught and allowed to suck blood from persons suffering from malaria. These mosquitoes were placed in little cages and shipped to England. Here two young men who had never suffered from the disease, and who lived in a region where there had been no cases of malaria, allowed themselves to be stung by the suspected mosquitoes. In the course of a few days *both developed the characteristic symptoms of the disease.* This experiment showed that the night air and the vapors from the swamps of the Campagna were harmless, and that the sting of a mosquito that had once bitten a

[1] The money cost of malaria in the United States has been estimated at one hundred million dollars a year. This cost takes the form of time lost from work, the cost of drugs, nursing, and medical service, the idleness of much fertile land, and so on. In India this disease kills over a million human beings a year, besides causing untold misery to millions of others.

malaria patient was dangerous. Mosquitoes raised from the eggs and allowed to sting a person do not cause the disease to appear; nor does drinking the water in which the mosquitoes develop. Today, nobody who knows the *facts* can have any doubt as to the relation between the mosquito and the transmission of the disease (see Fig. 152).

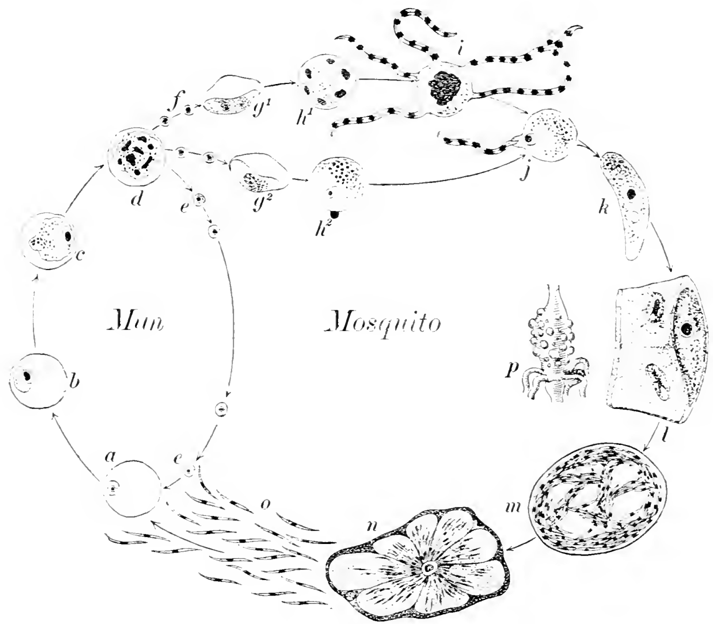


Fig. 152. The malaria parasite

The parasite attacks the red blood corpuscle of a human being, *a*, and when it has destroyed the corpuscle, *d*, it breaks up into a large number of *spores*, *e*, which may enter other corpuscles and start a new cycle. When blood containing the malaria organism, *f*, gets into the stomach of a mosquito (*Anopheles*), the protoplasm undergoes various changes, *g*, *h*, resulting in two sexual forms, *i*, *j*, which conjugate and produce a fertilized egg, *k*. This works its way into the wall of the insect's stomach, *l*, and breaks up into a large number of tiny bodies, *m*, which finally lodge in the insect's salivary glands, *n*. When the insect again stings a person, some of these bodies, *o*, get into the victim's blood and find their way into the red corpuscles, *a*, and the cycle begins again. *p* is the stomach of infected mosquito, showing swellings produced by the parasite

The most common mosquitoes found in various parts of this country belong to the genus *Culex*. This is a nuisance, but so far as is now known it does not transmit any disease to human beings (see Fig. 153).

245. Yellow fever. This disease, which has been in the past much more fatal than malaria, is found only in tropical or semitropical regions, although there have been epidemics of yellow fever as far north as Philadelphia, New York, and Boston. At the close of the Spanish-American War, while the parasite that causes the disease was still unknown, a commission of American physicians definitely proved that the mosquito *Stegomyia fasciata*, now called *Aëdes* (pronounced in three syllables) by the entomologists, was really the intermediary in the transmission of the disease, as had long been suspected by many students of the problem. The commission consisted of Dr. Walter Reed, Dr. James Carroll, and Dr. Jesse W. Lazear; they were assisted by a Cuban, Aristide Agramonte, who had recovered from the disease and was therefore immune. In one of the two cottages used the ventilation was intentionally very poor; in the other there was a mosquito-tight screen separating the two halves, and the ventilation was very good (see Fig. 154). Both cottages were well screened to prevent the entrance or escape of mosquitoes. In the first cottage three volunteers received cases of clothing and bedding from men who were suffering from yellow fever or who had died with the disease. They shook out these contaminated articles and slept in the soiled garments and in the soiled bedclothes for twenty days. Not one became infected. This experiment was repeated two times more, with no results to show

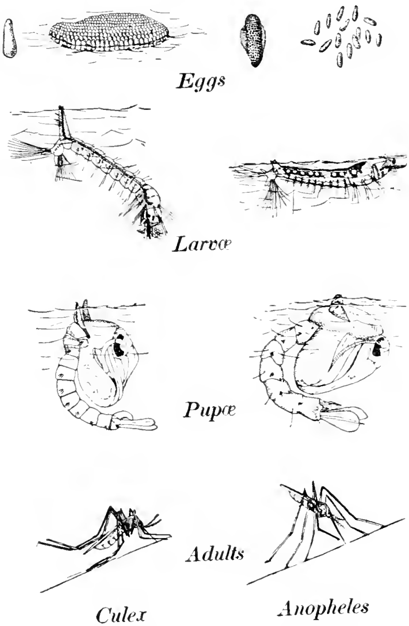


Fig. 153. Mosquito life histories

The mosquitoes of the genus *Anopheles*, which transmit malarial parasites, differ from the common *Culex* in every stage. We can readily distinguish the adults of the two genera by the fact that when at rest the *Culex* holds its body parallel to the resting surface, whereas in *Anopheles* the hind end of the body is farther from the resting surface than the head

the slightest connection between the vomits and excretions of the patients and the infection of new cases.

In the other building a volunteer allowed himself to be stung by a mosquito that had drawn blood from a patient some two weeks earlier. The volunteer had been in quarantine for two weeks, to make sure that he was not infected at the time he first came into the building. The bedding and other utensils were thoroughly sterilized. On the fourth day after being stung *he developed symptoms of the disease.* Other

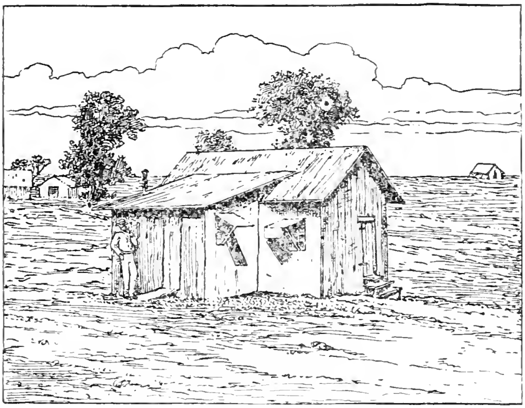


Fig. 154. Camp Lazear

In this building was conducted that part of the yellow-fever experiments which proved that the disease is *not* transmitted by infected clothing etc. The cabin consisted of a room, 14 by 20 feet, with two small windows facing south, closed with wire screens. Heavy wooden shutters excluded the sunlight. Entrance was through a small vestibule on the same side as the windows, protected by a wooden door and a screen door and separated from the main room by a screen door, to make perfectly certain that no mosquitoes could get in. This house was kept closed during the daytime and had a temperature of from 92° to 95° F. It was occupied for twenty nights by three American volunteers, and the test was repeated twice

volunteers, on the other side of the screen, breathing the same air but not stung by mosquitoes, remained unaffected. Ten or more individuals contracted yellow fever as a result of receiving bites from mosquitoes that had previously bitten sick persons, but not one who stayed on the other side of the screen was infected. In the course of the experiments Dr. Carroll and Dr. Lazear also became sick, the latter dying as a result.

The parasite that causes yellow fever was discovered in 1918 by the Japanese scientist Noguchi, working at the Rockefeller Institute.

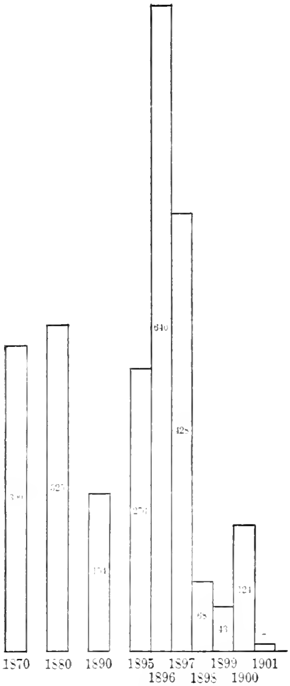


Fig. 155. The reduction of yellow fever in Cuba

The mortality from this disease had always been very high, but much worse in some years than in others. The year 1896 was unusually bad, and 1897 not much better. Immediately after the American army of occupation began to clean up in Havana, in 1898, the sanitary conditions showed marked improvement. By eliminating the breeding-places of mosquitoes, yellow fever has been completely banished from the island

246. Fighting mosquitoes. Each one of us can keep on killing mosquitoes on sight and feel that he is doing his duty, but the insects do not recognize city limits or state lines, and gayly fly from one man's grounds to another's. So far the only effective campaign against mosquitoes has been waged on a comprehensive scale by a whole community at a time. It seems that the best means of preventing malaria and yellow fever are (1) ditches to drain off marshy land; (2) cartloads of dirt to fill in low-lying spots; (3) oil on such puddles as cannot be filled or drained; and (4) lids or screens to cover up cisterns, tanks, or buckets in which water must be kept standing, while all old cans and other possible containers for water are scrupulously placed where the female mosquito cannot reach them, since the life history of the mosquito calls for quiet water for the laying of the eggs and for the growth of the larva and the pupa. Without such breeding-places one year would see the end of all mosquitoes in all civilized communities. In larger bodies of water, where fish may be kept, these will usually destroy the larvæ; but in the shallow margins, where the fishes cannot reach them, the mosquitoes have things their own way. It is necessary to keep the borders of ponds clear of weeds, sedges, etc.

The practical effect of exterminating the mosquito is shown by the decrease of malaria and yellow fever (see Fig. 155). During the various attempts of the French engineers to construct the Panama Canal, disease made the completion of the work very nearly impossible. When the United States took over the enterprise, the first step was the establishment of sanitary conditions, and the largest part of the problem was the extermination of mosquitoes through draining and filling in, and the inspection of inhabited regions to prevent the maintenance of breeding-places for the insects. Similar methods have since been used in many parts of the world. The health department of the government of Peru reports that there has been no yellow fever in that country since August, 1921.

247. Other disease-bearing insects. Fleas are found to be involved in a very serious combination injurious to man. The bubonic plague, which has in past times been the most dreaded of diseases, especially in Asia, was found (in 1894) to be caused by a specific bacillus; but the mode of infection was not known until quite recently. The Chinese had observed, centuries ago, that there was some connection between the dying of rats in large numbers and the appearance of a plague epidemic. Modern scientists set to work to find out whether the rat plague was in any way related to the human disease, and they found that the same bacillus was the cause of both. Then it was found that the plague spreads from rat to rat not by contact of the animals but through fleas that suck the blood of the sick rats and later bite others, thus transferring the infection. Further study showed that the plague is primarily a disease of rats, and gets into human beings when the fleas abandon dead rats and infect men and women. The plague has spread from the Orient, and cases have appeared at several ports in the United States at various times. The methods of dealing with this danger are directed not toward killing the bacteria but toward killing the rats and fleas. A ship coming from an affected port is thoroughly fumigated to kill the fleas and rats; special devices are attached to ropes and chains to keep the rats from leaving the vessel or from coming aboard; and a search is made for hiding-places in which rats may be concealed. In California it was found that the ground squirrels have become infected with the plague bacillus, and systematic patrols had to be established to catch rats and ground squirrels, which are regularly examined for possible

infection. To protect human life it is necessary either to exterminate some of our neighbors or to see that they keep well.

One of the special health problems that arose during the World War had to do with the transmission of trench fever, a disease that caused a great deal of suffering and incapacity, although it was seldom fatal. Volunteers from the ambulance and field hospital units allowed the blood of patients to be injected into their veins. In this way it was found that the disease is due to a germ too small to be seen with the most powerful microscope. Other volunteers allowed themselves to be bitten by lice taken from the bodies of patients; many of these developed the disease, while others, bitten by lice from healthy men, remained unaffected while living under exactly the same conditions. These experiments showed that the parasites are carried over by the louse. Measures were then taken to exterminate these insects, and so the disease was brought under control.

INSECTS IN RELATION TO DISEASE

1. Characteristics of insects that are related to human disease
    - Living things: can become hosts of parasites
    - Eating things: attack non-living organic matter (which may breed disease germs); attack human beings as well as other organisms
    - Moving things: carry bacteria about on their feet; carry microbes in the blood and other body juices
2. Insects as disease-germ carriers (typhoid fly)
    - Life history and habits of fly
        - Egg, larva, pupa: in manure, decaying food, etc.
        - Adult
            - Flies about freely
            - Feeds on all kinds of organic matter
            - Visits cesspools, garbage, etc., then food in kitchen and on table
            - Regurgitates materials taken up in one place while visiting another
    - Means of combating fly and protecting health
        - Destroy individual adults (swatting)
            - Important in early spring when survivors from previous summer are about to lay eggs
        - Destroy breeding-places
            - Screen manure, garbage, etc.; poison manure etc.
            - Prevent scattering of organic refuse
            - Screen and poison cesspools etc.
        - Screen houses, sleeping infants, etc.; protect food

3. Insects as intermediate hosts (mosquito)
   - Life history and habits of mosquito
     - Egg; larva; pupa
       - In still water
     - Adult
       - Flies about freely
       - Male does not take food
       - Female sucks juices from bodies of plants and animals
   - Life history of malarial parasite
     - Plasmodium, sporulation: in red corpuscles of warm-blooded host
     - Male and female cells: in capillaries near surface of host
     - Conjugation: in stomach of mosquito
     - Fertilized egg: in wall of mosquito stomach
     - (Blastomeres: from swellings on stomach wall to salivary glands: in red corpuscles change to plasmodia)
   - Yellow fever as insect-borne disease
     - No yellow fever among persons shielded from mosquito (*Aëdes*) even when exposed to contact with clothes, bedding, discharges, etc. of yellow-fever patients
     - Yellow fever among persons stung by mosquitoes that had previously stung yellow-fever patient, even when protected from all contact with patients and their clothes, discharges, etc.
     - No yellow fever among persons stung by mosquitoes other than *Aëdes*
     - No yellow fever among persons stung by *Aëdes* mosquitoes that had not previously stung patient
     - Yellow-fever parasite (*Leptospira icteroides*) recently discovered by Noguchi
   - Means of combating mosquito and protecting health
     - Kill individual adults
     - Prevent breeding
       - Drain swampy areas
       - Fill in
       - Oil waters that cannot be cleared away or drained
       - Clean up rubbish etc., in which water pools can form
       - Cover water barrels, fire pails, cisterns, etc. (screen)
       - Stock ponds etc. with fish
       - Keep edges of ponds and brooks clear of brush
       - Screen houses

4. Other insect-borne diseases
    Bubonic plague
        Carried by fleas from mammal to mammal (normally from rat to rat; sometimes from rat to man, then from man to man; sometimes from rat to ground squirrel, then to man etc.)
    Typhus fever (trench fever)
        Carried by body louse from mammal (man) host to next mammal host
    Sleeping sickness
        Carried by tsetse fly from mammal to mammal
5. Measuring importance of insects in relation to disease
    Relation between prevalence of flies and prevalence of typhoid and other intestinal diseases
    Relation between extermination of mosquitoes and elimination of malaria; of yellow fever
    Relation between rat-flea control and plague control
    Effects of extermination of insects upon human welfare

QUESTIONS

1. What is there to show that flies are dangerous neighbors?

2. At what stage in its life history is the fly most easily exterminated? Why?

3. What can the individual do for his protection if the community continues to tolerate flies?

4. What is there to show that mosquitoes are dangerous? How can we distinguish between mosquitoes that are dangerous and those that are merely a nuisance?

5. At what point in the life of the mosquito is it most easily exterminated? Why?

6. What is there to show that complete extermination of mosquitoes is a possibility?

7. What is there to show that extermination of mosquitoes eliminates disease?

8. What is there to show that malaria and yellow fever are not carried in the same way as typhoid fever?

9. Which is more economical, prevention or cure of malaria? Why?

10. How can a knowledge of the life history and habits of other animals be of use to mankind?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, chap. xxxiii, Communicable Diseases conveyed by Insects.

Folsom, J. W. Entomology, chap. ix, Transmission of Diseases by Insects.

Farmers' Bulletin 1408, The House Fly.

Farmers' Bulletin 734, Flytraps and their Operation.

Supplement 29, Public Health Reports. Transmission of Disease by Flies.

Farmers' Bulletin 444, Remedies and Preventives against Mosquitoes.

Farmers' Bulletin 1354, Yellow-Fever Mosquitoes.

United States Bureau of Fisheries. *Economic Circular 17*, Fishes Destructive to Eggs and Larvæ of Mosquitoes.

CHAPTER XXXII

WORMS AND OTHER CONTROLLABLE DISEASE AGENTS

Questions. 1. Can people support parasites without knowing it? **2.** What effects produced by parasites are not commonly recognized as disease? **3.** Can food that has not been exposed to dust or dirt still carry disease germs? **4.** Can disease be caused by organisms larger than microbes (bacteria and protozoa)? **5.** Are any worms dangerous to health? If so, what kinds? How?

248. Worms. Under older systems of classifying animals the name *worms* or the Latin form *vermes* was applied to a mixed group that had very little in common except the *shape* of worms (see pages 81, 82). The true ringed worms correspond to the more common idea of a worm; some of these are of great practical importance (see sections 330, 332). The rotifers, or wheel animalcules, are mostly microscopic and of no direct importance to us. In the other two branches, flatworms and roundworms, there are many species that live parasitically in the bodies of higher animals, and so they come to be of importance to us as injurious either to human beings or to domestic animals.

The liver fluke destroys many sheep by its ravages upon the liver of the host. The parasite reproduces sexually, discharging eggs and sperms. Fertilization takes place within the liver of the host, and then the embryo finds its way into the intestine by way of the bile duct. Discharged from the body of the host, the young animal swims about in water, or in dew upon grass, until it comes across a snail, into the body of which it penetrates. Here it undergoes several changes, which include a rapid multiplication by budding, and an escape from the snail into the grass, to the blades of which it attaches itself. From the grass it is taken up by grazing sheep and finds its way into the liver, again by way of the bile duct. The losses occasioned by this parasite were formerly enormous, for we knew neither cure nor prevention. But since we know that there can be no liver fluke in our sheep unless there are

certain snails about our pastures, the protection of the sheep is a comparatively simple matter.

249. The tapeworm. The name *tapeworm* is applied to several species of flatworms of the genus *Tænia* (Fig. 156). It has a comparatively simple structure, consisting of hardly more than a series of flat sacs containing excretory tubes and reproductive organs, with an anchoring organ, or holdfast, at the end of the series; but the life history is somewhat complex, since it includes adaptations for finding two different hosts in each generation. There are three or four species of tapeworms that inhabit the human intestine. The tapeworm can be dislodged and driven out by medical treatment (though sometimes with great difficulty), but its entry into the body can be more easily prevented by making sure that our pork and beef and fish are thoroughly cooked, since in the resting stage in the muscles of the secondary host it is easily killed by the heat.

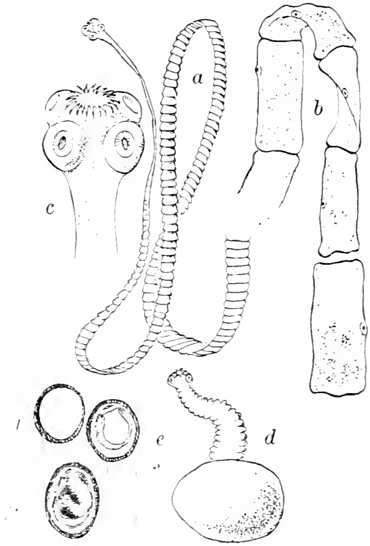


Fig. 156. The tapeworm

The adult stage, *a*, lives in the intestine of a human being and may grow to be many yards long. The segments, *b*, that make up the worm are hardly more than flat, thin-walled sacs that absorb food from the surrounding liquid in the intestine and discharge eggs and sperms into it. The so-called head, *c*, of the worm is an organ of attachment, made up chiefly of hooks and suckers; immediately back of this head new segments are constantly being produced. The segments farthest from the attachment are therefore the oldest — and largest. The fertilized egg hatches into a larva in a sort of capsule and is passed out of the body of the host with the feces. When taken into the body of another animal — a pig, for example — the larva works its way into the muscles of the new host, *e*, and settles into a resting stage for an indefinite time. When the flesh of this animal is eaten by a human being, the young worm projects the attaching head from the capsule, *d*, and fastens itself to the lining of the intestine

The secondary stage of the tapeworm is sometimes injurious to the other host also, forming what is called a *bladder worm*. Sometimes the human organism serves as the secondary host, and in this case the bladder worm may cause serious destruction of some tissue or organ.

250. Trichina. A widespread parasite belonging to the roundworm group is *Trichina*, which embeds itself in the muscles of the host, a mammal. A related parasite that produces trichinosis in human beings is called *Trichinella*, and it usually alternates between man and pig. Pork infested with the trichina is called measly pork; it should not be eaten. When the number of cysts is very small, a superficial inspection may not reveal them. It is always best, therefore, to cook pork so as to destroy the trichinella, rather than to take a chance of becoming infected.

Fig. 157. The American hookworm (*Necator americanus*)

The hookworm is large enough to be seen with the naked eye and looks like a small bit of thin white thread. It multiplies very rapidly in the intestine, and encysted eggs find their way to the exterior with the feces of the host. In the sandy soil the embryo emerges. The infection of human beings is brought about by contact with the contaminated soil

251. The hookworm. Early in this century investigations conducted under the direction of Dr. Charles W. Stiles of the United States Public Health Service disclosed the fact that the "poor whites" of our Southern states were suffering from an intestinal parasite, the hookworm, which depleted their energies, emotional and intellectual as well as physical (see Fig. 157). The announcement of this discovery was at first ridiculed, because nobody would take the "laziness germ" seriously. Self-righteous people said, "Laziness is laziness, and that's all there is to it—no use blaming sickness or worms for being lazy." Yet the fact remains that with the removal of the parasite these white folks appear to be equal to the best stocks in the country.

In parts of some Southern states most of the children and many of the adults go about barefooted, and children play on the ground. In some districts almost every inhabitant was infected when the investigations were made. Now we know that

both the remedy and the prevention are comparatively simple. The parasite can be driven from the host by the use of thymol and epsom salts. Infection can be prevented by sanitary arrangements. Where the ignorance and poverty of the people permitted the soil to be polluted by human excrement, the hookworm became widely distributed in a sandy region. With the installation of sanitary privies and modern toilets the parasite comes under complete control.

It is interesting to note that the negroes occupying the regions in which hookworm is common seem to suffer little or no injury from the parasite. It is believed that these organisms were first introduced into this country through the slaves brought from Africa in years past. Although the negroes may be infected, they appear to be immune to the serious damage produced by the parasites in white hosts. The reason for this is not clear, but similar racial differences in susceptibility to disease have been noted in regard to other parasites.

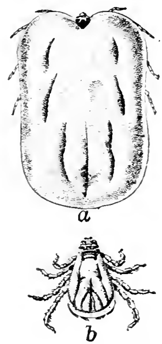


Fig. 158. The tick

This cousin of the spiders has been convicted of carrying dangerous disease germs by biting man and other mammals. *a*, female; *b*, male

252. Ringworm. The skin disease known as ringworm is due to a moldlike fungus (see page 79, Branch I, C) and has nothing to do with worms. The irritation and damage are annoying and unpleasant, but not serious. Treatment should be left to a physician, and persons who are infected should keep away from others, to prevent the spread of the parasite.

253. Itch mite. Apart from the often extreme irritation caused by itch, its chief danger is that the great temptation to scratch may lead to infection by some more dangerous parasite. The little animal that causes the itch is a *mite*, which is a nearly invisible relative of the spiders. The prevention of itch is largely a matter of personal cleanliness.

254. The tick. Another skin parasite related to the spiders is the tick, which is about an eighth of an inch long. This is a bloodsucker which may produce a painful bite, but its greatest danger is as a possible carrier of disease germs. The spotted fever (or Rocky Mountain fever) is known to be transmitted by this animal in man, and another species transmits the Texas cattle fever, which has been a very expensive scourge in this country (Fig. 158).

WORMS AND OTHER CONTROLLABLE DISEASE AGENTS

1. Meaning of term *worms*; general characteristics
   Main groups

Rotifers, or wheel animalcules	Flatworms	Roundworms
Ringed worms (not disease agents)	Liver fluke	Trichina
	Tapeworm	Hookworm
	Bladder worm	Vinegar eel

2. Life histories of some parasitic worms

Liver Fluke in Sheep	Tapeworm in Man	Trichina in Man	Hookworm in Man
Liver	Intestine	Intestine	Intestine
Eggs and sperms Fertilized egg goes to intestine Out with feces	Eggs and sperms Embryo encysts Out with feces	1. Enters muscles and encysts 2. Eggs and sperms Fertilized egg out with feces	Eggs and sperms Embryo out with feces
Swimming embryo in dew or puddles Eaten by *snail* Multiplies in body Discharged into grass	Embryo eaten by *pigs* or other backboned animals From gut to muscles Resting stage in muscles (or bladder)	Eaten by *pig* Multiplies in intestine Works into muscles and encysts; measly pork	Embryo in soil
Eaten by sheep	Eaten by man	Eaten by man	Through skin into human host Into the blood stream Into intestine

3. The hookworm (appearance, size, structure)
   Importance (effects upon host)
      Exhaustion of nutrition; (poisoning of system)
   Reproduction
      Eggs and sperms; embryo discharged with feces
   Entrance to new host
      Through skin; (contaminated food)

Prevention
  Protect soil from contamination
    Install suitable toilets
    Use privies in which discharges can be sterilized
  Prevent contact of skin with contaminated soil
    Wear shoes; provide suitable playgrounds for children
Extermination
  Prevent spread and reinfection; cure all infected persons

4. Arthropod parasites
   The tick; the itch mite
5. Ringworm (a fungus)

QUESTIONS

1. What is the use of knowing the life histories of parasites upon the human organism? How can such life histories be discovered?

2. How does the tapeworm injure its host?

3. Why is hookworm more common in the country than in the city?

4. What connection is there between the habits and customs of people and their likelihood of becoming infected with hookworm? with trichina?

5. What can the individual do to protect himself from tapeworm? from hookworm? from ringworm? from trichina?

6. What is the objection to scratching the skin when it itches? What is the advantage of scratching? How can one control the desire to scratch?

REFERENCE READINGS

United States Department of Agriculture. *Bulletin 880*, Effects of Pork-Curing Processes on Trichinæ.

United States Department of Agriculture. *Bulletin 260*, The Dog as a Carrier of Parasites and Diseases.

Public Health Reprint 596, The More Common Helminthic Infestations.

Farmers' Bulletin 569, Texas, or Tick, Fever.

Farmers' Bulletin 1057, Cattle Fever Ticks and Methods of Eradication.

Farmers' Bulletin 798, The Sheep Tick and its Eradication by Dipping.

Bureau of Animal Industry. *Bulletins 130, 152*, Studies on Biology of Texas-Fever Tick.

United States Department of Agriculture. *Bulletin 147*, Effect of Cattle Tick on Milk Production of Dairy Cows.

United States Department of Agriculture. *Bulletin 553*, Chicken Mite.

CHAPTER XXXIII

ARTIFICIAL IMMUNITY IN THE CONTROL OF DISEASE

Questions. 1. What happens when parasites invade the body? 2. If microbes are present nearly everywhere, how can infection be entirely prevented? 3. Why can one have certain diseases only once? 4. How can juices taken from a sick animal help one get well? 5. Isn't vaccination dangerous? 6. How can we tell that vaccination helps? 7. How can we tell that antitoxin helps? 8. How does getting chilled make one sick? 9. Are diseases inherited?

255. Immunity and susceptibility. Individuals differ so greatly that some are much more sensitive or much less sensitive to a given substance or a given stimulus than are others. It is a matter of common observation that some people catch cold more easily than others; some more frequently have boils or pimples; some are very susceptible to the effects of alcohol or some other chemical; some are more susceptible to typhoid or to diphtheria. There are also racial differences. Thus, the dark-skinned races are less susceptible to malaria and to hookworm than are the white races; on the other hand, the white races are less susceptible to tuberculosis and measles than are the dark races. Moreover, there are important *specific* differences (that is, differences connected with species). Hens are quite indifferent to the action of morphin. Rabbits are insensitive to atropin. In the same way human beings are quite insensitive to diseases that are serious or even fatal to birds or cattle. Such immunity is called **natural immunity** and is inherited. In many cases it probably depends upon the chemical peculiarities of the blood or other body juices. In other cases it probably depends upon the quick reaction of the living cells to the poisons and other products of the parasites.

256. Immunity modifiable. Many of the bacteria which cause diseases are present in most of us a great part of the time; yet we are not constantly getting sick. A good deal depends upon the *condition* of the organism at a given time. Pasteur performed an experiment which taught a very important lesson regarding the modification of immunity by conditions. If the bacteria of the cattle disease *anthrax* are injected into a hen, the animal does not seem to be affected one way or the other. Pasteur placed a hen in a dish of cold water until the animal's blood was lower than normal (104° F. for the hen). When chilled in this way, the animal succumbs to anthrax. Anything that influences the body unfavorably may thus increase the susceptibility or overcome the resistance of the body. It is therefore important to guard the natural immunity of the body against the destructive effects of worry, of undue exposure to extremes of temperature, of excessive fatigue or insufficient rest and sleep, of improper nutrition, of prolonged hunger and thirst, and of drugs, alcohol, or other substances that interfere with the action of the blood as a living tissue.

Disease itself may lower the resistance of the body. After pneumonia, for example, one is more likely to catch other diseases; and he is more likely to catch pneumonia after typhoid or measles than he is ordinarily. One cannot afford to be sick even a little; even a slight cold may open the way for more serious trouble. On the other hand, one who *recovers* from a certain disease becomes almost wholly immune to that disease. As the common saying goes, "You can't have measles twice." The same is true of mumps, whooping cough, scarlet fever, typhoid fever, and smallpox. How is this immunity brought about?

257. Antitoxins. The venom of a rattlesnake, a certain protein found in the seed of the castor-oil plant, and many other proteins act as poison in the body of another organism. When one of these is brought into the blood of a human being, for example, a chemical reaction is started in the living cells, especially the white corpuscles. As a result a new substance is

produced which counteracts, or *neutralizes*, the poison. Poisons of this class are known as *toxins* (from a Greek word meaning "poison"). The substance produced by the living cells as a reaction to a toxin is called an **antitoxin**. An antitoxin is always specific; it will neutralize the toxin that brought about its formation, but no others. The best-known toxins are those produced by certain bacteria, especially those that cause lockjaw

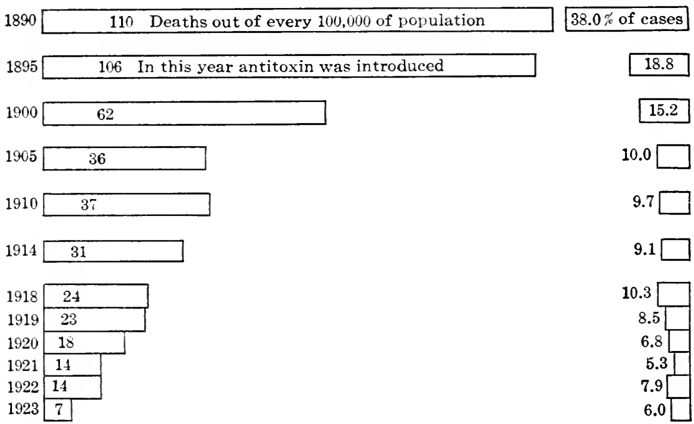


Fig. 159. Reduction in deaths from diphtheria in New York City (Manhattan and Bronx)

The numbers and rectangles on the left show the number of deaths out of every hundred thousand of the population. The numbers on the right show how many fatalities there were for every hundred cases of the disease. Note the rapid falling off both in the *proportion* and in the *number* of deaths after the year 1895, when antitoxin was first used. The great reduction in recent years is due to the use of the Schick test for susceptibility with artificial *immunization*

and diphtheria. When a quantity of toxin, not enough to kill, is injected into the blood of an animal (for example, a horse), the cells begin to throw off antitoxin. They will produce more than enough antitoxin to neutralize the poison received, just as you might strike at an annoying mosquito much harder than was necessary to drive it away. After the poison has all been destroyed, there will be a quantity of antitoxin left in the blood.

If now a larger quantity of poison is introduced, some of it will be at once neutralized by the free antitoxin; and if the animal is in good health, an additional quantity of antitoxin will be produced. In this way we may increase the amount of antitoxin in the blood until it contains several hundred times as much as would be necessary to neutralize very many fatal doses of the poison.

The use of antitoxin is coming to be quite general in the treatment of diphtheria and in the *prevention* of diphtheria in people who have been exposed to infection. We can measure the value of antitoxin in terms of lives saved, in two different ways: (1) Out of all the population, what reduction is there in the number killed by diphtheria? (2) Of all the people who get the disease, what reduction is there in the proportion that die? Both of these questions are answered in part by the diagram in Fig. 159. The efficacy of the treatment depends upon applying it early after the infection, so that the bacteria may get no headway in the body of the patient. The advantage of the early use of antitoxin is shown in Fig. 160.

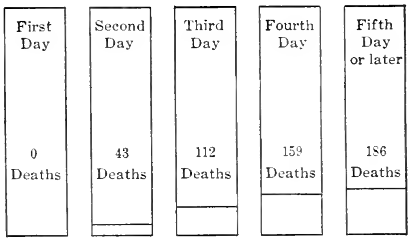


Fig. 160. Danger in delay

Each rectangle represents one thousand children suffering from diphtheria. Antitoxin was administered to all the children on the days indicated. The number of deaths in a group increases with each day's delay in the use of antitoxin

Antitoxin serums have been prepared for *tetanus* (lockjaw), for snake bite, for scorpion sting, and for castor-bean poisoning.

258. Precipitin. Another type of reaction to foreign protein is illustrated by the results of introducing white of egg into the blood of a mammal. We know that in the stomach this substance is readily digested, but in the blood of a mammal (a rabbit, for example) it will have a peculiar effect. If the blood is allowed to clot after a number of injections, the serum will react to fresh white of egg by forming with it a

solid *precipitate*. The unknown substance in the serum is called a **precipitin**, and, like antitoxin, it is always *specific*: a precipitin formed under the influence of a goat protein will react only to that protein. This fact has been put to use in several ways:

1. The precipitin test enables us to distinguish between a drop of blood (or other material, like meat) from a horse, let us say, and a drop of blood from a dog or a human being. This is often of great importance in legal trials.

2. Experiments now going on make it likely that this principle can be applied in the *diagnosis of disease*, enabling us to tell without doubt which of several possible parasites are present in a patient.

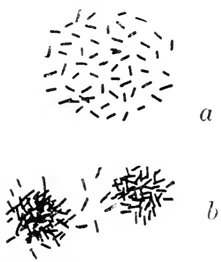


Fig. 161. Agglutination of typhoid bacilli

a, bacilli swimming about separately; *b*, the same clumped together, or agglutinated. The Widal test for typhoid fever consists in mixing a few drops of serum from the suspected person with a quantity of typhoid bacteria under the microscope. If agglutination takes place, the person is known to be infected with typhoid germs

259. Agglutinins. If some serum from the blood of a typhoid-fever patient is mixed with a few drops of liquid that contains living typhoid bacilli, the bacteria will all be clumped together in masses. There is apparently formed in the blood (under the stimulus of some typhoid protein) a substance that acts upon these bacteria by sticking them together, or *agglutinating* them. Such substances are called **agglutinins**, and, like precipitins and antitoxins, they are specific. The bacteria are not killed by the agglutinin, although their free action is interfered with (see Fig. 161).

260. Cytolysins. When we examine the blood of an animal under the microscope, we can see the corpuscles, red and white, move about unaffected by one another; but if a little blood of one animal is injected into the veins of another, the foreign red corpuscles are shortly destroyed or dissolved by a specific substance. This cell-dissolving substance is not present in the blood all the time; it is formed only after the foreign cells are introduced. These cell dissolvers, or **cytolysins**, are formed in response to any foreign cells or tissues, or to various bacteria, and they are always specific. Thus, the serum of a person who has been treated with dead typhoid cells will dissolve typhoid bacteria, but not other species of bacteria. These facts are used practically in the fight against typhoid fever. A measured quantity of *dead* typhoid germs is injected into the body. The specific typhoid-cell dissolver, or cytolysin, is formed by the action of the living cells of the body, especially the

white corpuscles. Later, when typhoid germs get into the body, they are dissolved by the cytolysin already present.

Other specific cytolysins have been produced and will be of value for diagnosis, for identification of materials, and for the cure or prevention of disease.

261. Vaccination. The blood meets the invasion of foreign bodies or foreign substances in several different ways. These reactions depend upon the vital properties of the cells of the body, and especially of the white corpuscles. By understanding these blood reactions we can increase the immunity of the body with respect to certain diseases, and even develop artificial immunity.

In the case of diphtheria and of some other diseases the use of antitoxin establishes what we may call a *passive* immunity, since here the blood of the patient does nothing actively: it simply makes use of the previous activity of some other animal's blood. Such immunity usually lasts but a limited time.

An *active* immunity is one acquired by stimulating the cells to produce their own counteracting substances. In typhoid fever, for example, the injection of dead bacilli stimulates the body to produce a typhoid cytolysin. The process of inducing an active immunity is called **vaccination**. Successful methods of vaccination are now in use against several diseases besides typhoid and smallpox. That vaccination is a genuine means of control is demonstrated by comparing death rates from smallpox in different communities (Fig. 162), or by comparing typhoid death rates in the army, which used vaccination, with those in the civil population (Fig. 163).

The term *vaccination* comes from the Latin *vacca* (cow), and was first applied to the practice of infecting people with pus from cowpox, about the end of the eighteenth century. Observers had found that those who had a mild attack of pox, by infection from a cow, were later immune to smallpox. This disease was so common at one time that hardly one person out of ten escaped it. That cowpox is a variety of smallpox, and that the germs of cowpox do actually make human beings immune to smallpox, was established by Edward Jenner through careful experiments.

At present the term *vaccination* is used to designate any process by which active immunity is induced artificially. There are three types:

1. The use of living bacteria, as in smallpox vaccination.
2. The use of dead bacteria, as in antityphoid vaccination.

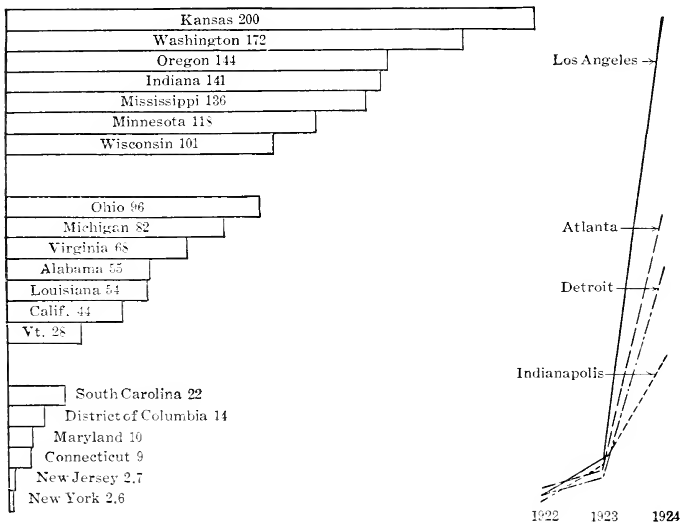


Fig. 162. Vaccination and smallpox

The bars show the relative amount of smallpox (number of cases per 100,000 of population) in nineteen states and the District of Columbia in 1915–1920. At the bottom are the six areas in which compulsory vaccination prevails. At the top are seven states in which there is no compulsory vaccination, but rather opposition to vaccination in many regions. In the middle group are states in which conditions seem to be getting worse; general vaccination is not enforced, or is opposed, in these states. On the right is a graph to show increase in the number of smallpox cases in four American cities during recent years

3. The use of toxin, as in diphtheria vaccination by means of a mixture of toxin and antitoxin in certain proportions. The antitoxin is a protective agent, while the toxin stimulates the protoplasm of the child to produce its own antitoxin.

262. Biological tests of disease. It is often of advantage to know whether a person is already suffering from a given disease. Very often an early diagnosis may make the difference between

saving a life and delaying proper treatment until it is too late. A knowledge of the way the blood reacts to various kinds of parasites has made it possible to make quick diagnosis in some cases; a knowledge of chemical changes produced in the body

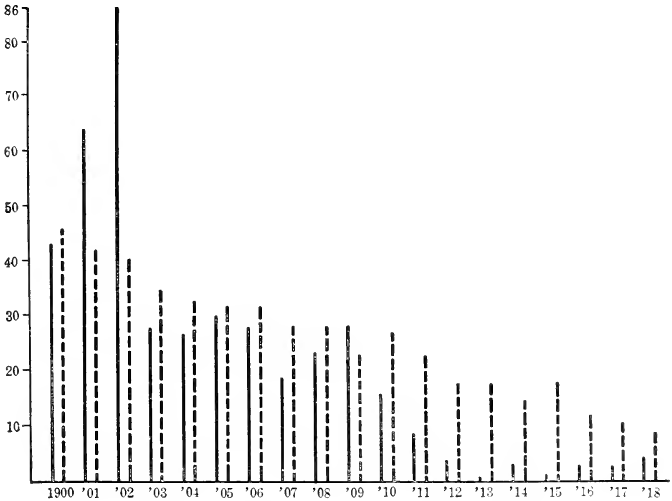


Fig. 163. Vaccination and typhoid fever

The solid lines represent the United States army deaths from typhoid fever, per 100,000; the dotted lines the corresponding numbers for the civilian population. In 1909 vaccination against typhoid was made optional in the army; there was an immediate improvement of conditions. In 1911 vaccination became compulsory in the army. Although there has been a steady improvement for the whole population, the contrast between the vaccinated army and the generally not-vaccinated civilian population is very striking

by some parasites helps in other cases, and in still other cases it is possible to examine the bacteria directly. Swabs of cotton that have been sterilized may remove from the throat colonies of diphtheria bacilli, or the sputum (saliva) may contain the bacilli of tuberculosis. These can be examined under the microscope.

The Widal test for typhoid has already been mentioned (see Fig. 161). A test for susceptibility to diphtheria, devised by

Dr. Bela Schick, an Austrian physician, works on a somewhat similar principle. The Schick test has been applied to half a million children in New York City alone, and those who appeared susceptible were treated with the toxin-antitoxin mixture, making them immune. In this way many cases of diphtheria are prevented, and it is reasonable to hope that in time this disease will be as rare in civilized communities as is smallpox or plague.[1]

263. Disease and heredity. In a given family many members may have suffered from the same disease, as tuberculosis. We know now that tuberculosis and other diseases are not inherited in the same sense as the color of the eyes or the shape of the thumb is inherited. Where tuberculosis runs in a family, two facts are to be distinguished:

1. If one member of a family has the disease, the other members are more likely to be *exposed to infection* than they would be otherwise, and so the disease spreads in that family.

2. Where a person has tuberculosis (or any other disease), the indications are that this person *has not a natural immunity* to the disease; in other words, he is susceptible to it, or has a disposition toward it. Now it is this natural susceptibility (or immunity) which is inherited, and not the disease. *No matter how much susceptibility one had to a given disease, he would not contract that disease unless he was exposed to infection by the specific microbes that cause that disease.* This point is tragically demonstrated by the rapid dying out of the inhabitants of certain of the South Sea Islands. The natives of these islands appeared to be extremely susceptible to measles and tuberculosis, as well as to various other diseases that are common in Europe and America. The natives had never experienced these diseases, however, until the foreigners brought the germs to them. Then the natives died out very rapidly.

[1] Experiments have been carried on in Chicago by Drs. George and Gladys Dick, to find a susceptibility test for scarlet fever. This Dick test has been tried out by physicians in several cities and promises to be a useful aid in preventing sickness.

ARTIFICIAL IMMUNITY IN CONTROL OF DISEASE

1. Susceptibility variations
   - Kinds
     - Individual variations
     - Family variations
     - Racial variations
     - Specific variations (that is, differences between species of animals)
   - Probable reasons
     - Chemical differences in blood
     - Chemical differences in metabolism
       - The reaction products of protoplasm
       - The by-products of metabolism
     - Differences in other behavior of protoplasm
     - Possibly physical differences in cell walls etc.
2. Immunity
   - Natural
     - Inherited chemical qualities of blood etc.
     - Inherited reaction habits of white corpuscles
     - Inherited reaction habits of protoplasm
   - Acquired
     - Passive
       - Use of drugs (for example, quinine)
       - Use of antitoxin
       - Use of other aids to resistance
     - Active
       - Recovery from specific disease
       - Vaccination or inoculation
         - Living parasites
         - Non-living parasites
         - Toxin
   - Broken
     - Malnutrition
     - Exhaustion
     - Fatigue
     - Chilling
     - Poor circulation
     - Effects of previous sickness
     - Constipation
     - Worry and nervous strain

Overwork
Alcohol
Activity of parasites that exhaust without themselves breaking out in an acute disease

3. Reaction of organisms to parasites
   Phagocytosis (white corpuscles swallow invading bodies)
   Chemical response (the formation of neutralizing or counteracting substances; antibodies)
      Antitoxins (poison neutralizers)
      Cytolysins (cell dissolvers or bacteria destroyers)
      Agglutinins (glue or clot up invading bodies)
      Precipitins (throw out foreign proteins etc. as solids)
      Opsonins (modify foreign bodies so that white corpuscles can swallow them)
4. Uses made of specific reactions
   Tests
      Widal test for typhoid
      Schick test for diphtheria susceptibility
      Tuberculin test for tuberculosis
      Tests for hay fever
      Dick test for scarlet-fever susceptibility
      Agglutinin and precipitin tests for specific sources of blood stains and other organic materials
   Vaccinations
      Smallpox
         Cultivated on healthy calves
      Typhoid, Paratyphoid, Dysentery — Often used together as "triple vaccine" against intestinal disorders
      Whooping cough
      Boils and pimples
      Common colds
      Diphtheria (toxin-antitoxin)
      Rabies
         From spinal cord of rabbits inoculated with hydrophobia
5. Measurement of results
   Decline in sickness rate and mortality rate of diphtheria
      Since discovery of germ
      Since discovery of antitoxin
      Since general use of antitoxin
      Since application of Schick test

Decline in prevalence and death rate of smallpox
  Where vaccination is generally employed
  Where vaccination is not employed
Decline in prevalence and death rate of typhoid
Decline in prevalence and death rate of plague

6. Heredity and specific diseases
   Difference between inheriting a disease and inheriting susceptibility to it
   Danger of infection from members of family
   Need for special precautions where immunity is absent
     Build up general systemic vigor
     Avoid possibly infectious contacts
     Avoid conditions that would break down resistance

QUESTIONS

1. During an epidemic, why are some people more likely to get sick than others?

2. Why is anyone more likely to get sick at one time than at another?

3. Why are not doctors and nurses, who are brought more in contact with sick people, more often sick than others?

4. How can we find out whether a person is susceptible to a given disease?

5. What is the advantage of having physicians report certain diseases to the state or city health officer? What is the disadvantage?

6. How can we tell that a person carries the germs of a disease, if he does not show the symptoms of that disease?

7. How can a person have the germs of a disease in his body and not show the symptoms?

8. What is meant by vaccination?

9. For what diseases is vaccination possible?

10. Is it desirable that everybody should be vaccinated? Should everybody be vaccinated against all possible diseases? What should decide the question?

11. What are the advantages of general use of vaccination? What are the disadvantages?

12. How does a knowledge of the family's history help in protecting health?

13. How does travel to new regions bring dangers to health?

14. Why are the death rates higher for some diseases than for others?

15. Why are the death rates for a given disease higher in one state or city than in another?

16. What use can we make of a comparison of death rates of different communities for different diseases? What use can we make of a comparison of the death rates for various diseases in our community with the death rates in other communities?

17. What diseases have shown diminishing danger in your community during the past ten years? What brought about the change?

18. What diseases have shown increasing danger in your community during the past ten years? What brought about the change?

19. If we know that some diseases increase their injury to the community, and others diminish their injury, what can we do with the knowledge?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, chap. xxxii, Some Parasitic Diseases and their Prevention.

Farmers' Bulletin 449, Rabies or Hydrophobia.

Farmers' Bulletin 1069, Tuberculosis in Live Stock, Detection, Control, and Eradication.

Bureau of Animal Industry. *Circular 190*, Vaccination of Cattle against Tuberculosis.

Bureau of Animal Industry. *Bulletin 121*, Need of Controlling and Standardizing Veterinary Tetanus Antitoxin.

United States Department of Agriculture. *Circular 249*, Tuberculin Testing of Live Stock.

United States Department of Agriculture. *Bulletin 70*, Immunization Tests with Glanders Vaccine.

United States Department of Agriculture. *Bulletin 166*, Ophthalmic Mallein for Diagnosis of Glanders.

Public Health Reprint 778, Diphtheria, its Prevention and Control.

CHAPTER XXXIV

COMMUNITY ACTIVITIES RELATED TO HEALTH

Questions. 1. Why can we not be left to look after our health entirely by ourselves? 2. Why can we not look after our own food supplies? 3. Why do we have to pay taxes toward protecting food and water supplies? 4. How can other people influence our health? 5. How can we interfere with the health of other people? 6. How can we help other people with their health?

7. What dangers to health can be better guarded against by the individual than by the community? 8. What dangers to health can be better guarded against by the community than by the individual? 9. What is the objection to the use of preservatives to keep milk or other food from spoiling? 10. What have prohibition laws to do with health? 11. Why can we not leave people to suffer from the results of their own ignorance or negligence?

264. Why coöperation is necessary. The concentration of populations exposes each one of us to possible injury from the negligence or even ignorance of more and more neighbors. It removes us far from the original sources of our food and other necessities. It makes impossible the securing of suitable supplies of water and other necessities on a small (individual) scale. Science brings out important facts that bear upon our health faster than the individual can inform himself, and in most cases these facts can be applied only on a large scale. The coöperation of neighbors in larger and larger groups (eventually including the whole civilized world) is absolutely essential to protect the individual from many dangers and to secure for him what he must have in order to live decently. As Benjamin Franklin is reported to have said on a certain historic occasion, "We must all hang together, or assuredly we shall all hang separately."

265. Water supply. Water is a fundamental need of life. When we get away from the small farm, it becomes increasingly difficult to supply the community with enough water of the right kind, in a suitable condition, without going to some great distance. In towns and cities that still depend upon separate

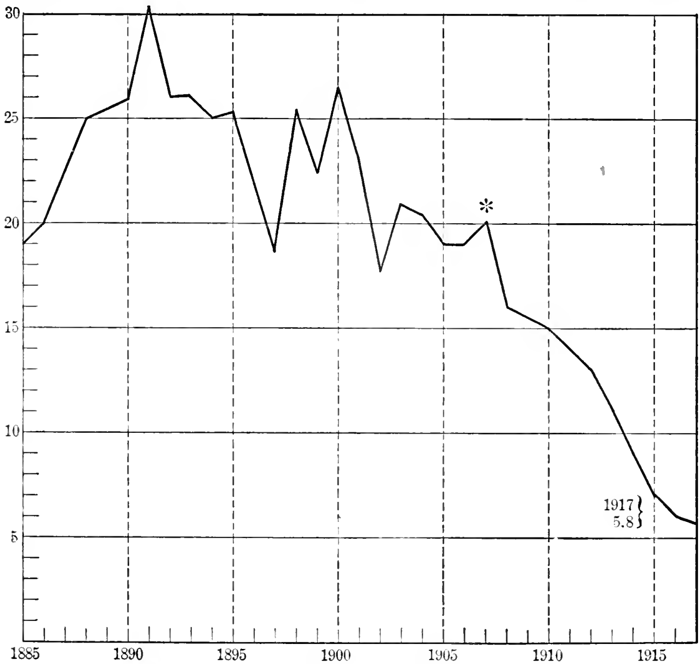


Fig. 164. Typhoid and water supply

For twenty years the deaths from typhoid fever fluctuated between 18 and 31 per 100,000 of the population. Since 1907, when the state authorities (New York) took charge of water regulation, the death rate from this disease has steadily declined

wells or springs for water the amount of illness and the proportion of deaths are likely to be much greater than in communities that have a central water supply. To be sure, if the central supply becomes contaminated, more people are likely to be injured in a short time; but it is easier to control the sanitary condition of one large reservoir than that of hundreds of wells.

The contamination of wells, rivers, and lakes with the germs of disease can be brought about only by discharges from persons harboring the parasites (see Fig. 164). Wherever there is a sewerage system, the law should require that every house be properly connected with the sewer. There is unmistakable evidence that the general health is better among people who use modern toilets than among those who do not. It is also certain that the latter are frequently sources of danger to others, since the contaminations work their way through the ground to poison the water supplies upon which others are dependent. Thus again we see the interdependence of people, living, it may be, at considerable distances from each other, or in different states. We cannot be secure while others are in danger.

266. Food protection. A large part of our food comes to us in sealed packages; we do not know where the food is made, or of what materials. Growing commerce has brought us food products of foreign lands, in regard to which we have no standards and no judgment. As individuals we cannot tell anything of the nutritive value or possible dangers of these wares. We cannot tell from the looks or the taste whether any of it contains harmful preservatives or coloring matter, or whether it contains any adulterants. It has become altogether too easy for unscrupulous dealers or manufacturers to mix cheaper materials with those that already enjoyed a good market, or to substitute cheaper materials for more expensive ones. Spices and coffee were thus among the first things to be adulterated.

The scientists have been increasing their knowledge about the relation of food to bodily health and efficiency, and our civilization has separated people more and more from the sources of their everyday needs. It has therefore become necessary for the public, through its official agents, to extend the protection of the buyer still farther. It is not sufficient that we get full measure. It is not sufficient that we get goods correctly labeled. We must be assured (1) that what is offered is *suitable* for our purposes, and (2) that it is *harmless*.

267. Danger from action of bacteria. Because we are increasingly separated from our food sources, in time as well as in space, new dangers have arisen. These have to do (1) with the

possible decomposition of food, making it unfit for consumption, and (2) with the possible contamination of food with disease-causing bacteria.

In the canning and packing of meats, fruits, vegetables, fish, and so on, food that is not strictly fresh has often been put into the containers, with its odor concealed by the use of spices and other flavoring substances. Decomposed food is a real source of danger, for it contains, in addition to the proteins, fats, and carbohydrates for which we eat it, poisons produced by the decay bacteria. Regulations concerning the sale of prepared food in which such materials are present have been adopted by the governments of nearly all the states, and the shipment of such preparations from one state to another is prohibited by federal laws. Many cities also have special ordinances that authorize the officials to seize and destroy any such unsuitable food that they may find, in addition to penalizing the dealers or manufacturers by means of fines or imprisonment.

268. Use of preservatives. The use of preservatives, such as benzoate of soda, in canned or prepared foods has long been a matter of dispute. As a result of careful experiments on the possible injury that such substances may cause it was found that, although benzoate of soda is injurious when taken by human beings in large quantities, one would have to eat a peck or more of catsup containing this preservative to get enough to hurt him. The objection to the use of preservatives is that they make possible the adding of slightly decomposed vegetables in the manufacturing process. At the present time our federal laws protect us only by requiring the manufacturer to state on the outside of the package what amount, if any, of preservative is present. The buyer has to take the chance of seeing this warning on the package, and of knowing its full meaning when he does see it. Moreover, this regulation applies only to merchandise that passes from one state to another.

269. Food infection. The infection of food by disease germs is a purely local problem, since it has to do with food brought to the consumer day by day. Many cities have adopted regulations requiring dealers to protect their wares from exposure to dust, insects, or other means of infection, such as handling by

MILK STANDARDS

I. Chemical Standards

a. Milk must not contain more than 88.5 per cent of water.
b. Milk must contain not less than 11.5 per cent of milk solids.
c. Milk must contain not less than 3 per cent of fats.
d. Milk must not be drawn from cow within fifteen days before nor within five days after calving.
e. Milk must not be diluted with water or other liquid, or be otherwise adulterated with foreign substance.

II. Bacteriological Standards

a. All cows must be in good physical condition and tested at least once a year with tuberculin, tagged, and registered with the authorities within three days.
b. Dairy conditions and methods must be scored and the score registered or certified.
c. The milk must be tested and certified from time to time.

Grade A Milk (Raw): Must not contain more than 100,000 bacteria to the cubic centimeter, and must come from dairies that score at least 75 per cent.

Grade A Milk (Pasteurized): Must not contain more than 200,000 bacteria per cubic centimeter before pasteurization, nor more than 30,000 between pasteurization and delivery to consumer, and must come from dairies that score at least 70 per cent.

Grade B Milk (Raw): Must not contain more than 300,000 bacteria per cubic centimeter, and must come from dairies that score at least 60 per cent.

Grade B Milk (Pasteurized): Must not contain more than 1,000,000 bacteria per cubic centimeter before pasteurization, nor more than 100,000 on delivery to consumer, and must come from dairies that score at least 55 per cent.

These standards, with slight variations, have been adopted by boards of health and by dairy associations in the most progressive cities all over the country.

inconsiderate customers. They have regulations as to the refrigeration of meats and fresh fish, the management of kitchens for hotels and restaurants, the handling of food served in public places, the conduct of bakeries and refreshment parlors, and so on. The most elaborate regulations have been adopted in regard to milk, since milk is the most easily spoiled of all our foods, and since it is at the same time so indispensable to many people, especially children and infants and the sick.

270. Milk. While the milk in the udder of the cow may be quite free of any contamination, by the time the milk has been poured from the pail to the can it is sure to have many bacteria floating in it. The high temperature of the milk fresh from the cow makes the multiplication of the organisms proceed very rapidly. By the time the milk is ready for delivery in the city it contains a large number of bacteria in every drop. On page 355 are given the rules for the care of milk intended for city markets. There is a biological reason for every rule given, and the reason should be clear to the student in every case. It has been found practically impossible to obtain milk in large quantities without excessive numbers of bacteria. For this reason the practice of *pasteurization* has come into more and more general use. This consists in raising the temperature of the milk to about 140°–155° F. and keeping it there for from ten to twenty minutes. Pasteurization does not, of course, remove the bacteria: it only kills them. Where it is impossible to get certified milk it is worth while to pasteurize the milk at home, using a steam cooker or a double boiler (see Fig. 165).

Preservatives should never be used in milk, since the only kinds that would not show themselves by taste or odor are apt to be injurious.

271. Official recognition of microbes. In every progressive community the danger to health and life that lies in various invisible microbes is officially recognized in public regulations and government activities. We are protected from these dangers even where we are ignorant of their existence, and even where we "don't believe in microbes." A mere enumeration of the

various lines of control and activity involved will give us an idea of how far-reaching is our dependence upon our environment and upon one another. In addition to the inspection of slaughterhouses we regulate the cleaning of glasses in which soft drinks are sold, the presence of drinking-cups in public places, the wrapping of bread before it leaves the bakery, and the disposal of garbage and ashes.

Many diseases are subjected to quarantine and placarding. There are provisions for supplying vaccines, serums, etc., through

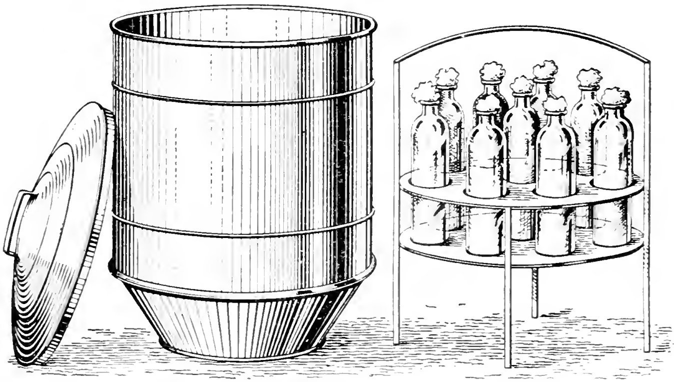


Fig. 165. Pasteurizing milk at home

A double boiler or a simple steam cooker can be used for sterilizing the baby's milk as well as for other purposes. With a glass thermometer and a clock to help, one can soon learn to use this valuable and inexpensive form of health insurance

public laboratories, and for supervising the manufacture and sale of such products for profit. There are official laboratories for making accurate examination of blood and other specimens obtained from patients for the purpose of diagnosis. Provision is made for inspection of dwellings, schools, factories, and other places where people live or assemble, in order to determine the sanitary conditions; for excluding sick people from schools, theaters, etc.; for supplying vaccination where needed; for disinfecting discharges from the bodies of sick people; and for disinfecting premises that have been infected. In some cities,

too, there are visiting nurses, ambulance service, and public hospitals, all helping to keep down the amount of sickness and to reduce the suffering.

Licenses are required of physicians, dentists, druggists, nurses, and midwives. Rules are provided to guard against the transmission of disease by barbers, manicurists, and masseurs.

The keeping of animals within the city limits—dogs and cats as well as horses, cows, pigs, and poultry—is regulated for preventing the multiplication and spread of bacteria. In many cities dogs must be muzzled; this plan must in time eliminate all rabies from towns, since this disease is transmitted by the bites of dogs. The disposal of dead animals is also regulated.

In all up-to-date communities, spitting in public places and using public towels are prohibited. Street cars, boats, and other public conveyances must be kept thoroughly clean and sanitary. In many towns provision is made for baths that are either entirely free for all to use or are open for a nominal fee.

For the purpose of enabling the public to *measure* from time to time the progress made in matters of health, population, etc., many states and cities require the registration of all births as well as of all deaths, and the notification of the health authorities in every case of communicable disease. An example of progress in regulating health conditions is shown graphically in Fig. 166. In general it may be said that the best index of the health conditions in any community is to be found in the infant death rate, that is, the number of babies under one year of age who die out of every thousand born each year (see table, p. 374).

272. Prohibitive regulations. We can no longer say, "I have a right to eat or drink what I like." Of course it is no one's business if I prefer ice cream to apple dumpling, but in the case of drugs and intoxicants the question is one of protecting people from their own ignorance or from vicious habits and customs.

The conditions that have made it necessary for the public to undertake the regulation of water and food supplies have also made it necessary for the public to undertake the regulation of the sale of drugs. All people are interested in their health, and

most people are ignorant in regard to the conditions of health. The vast patent-medicine business represents a great amount of suffering as well as a great amount of injury caused by supposed

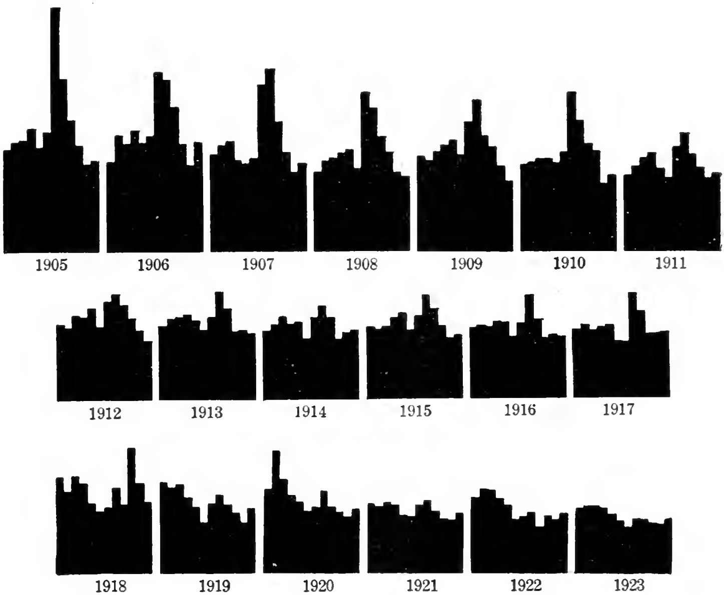


Fig. 166. The reduction of infant mortality in New York City

This diagram shows, month by month, for a period of nineteen years, the proportion of infants (under one year old) who died to the infants born. There is a variation from month to month, with a very striking increase in the number of deaths during the summer months. When the records showed this big jump in 1905, physicians and nurses and sanitary experts at once took steps to discover the causes and to devise preventive measures. Year by year we can see a steady improvement. So much effort has been made to protect the children for the bad month of July that in recent years this month has shown off rather better than the others, and August and September have become the bad months. With increased knowledge, and especially with wider application of the knowledge we already have, the high points on these black spots will be cut down, and the general level of the spots will be considerably lowered. This is but another way of showing that applied biology saves hundreds of thousands of lives

remedies. The regulation of what some consider private business is accordingly being extended so as to require manufacturers to state what their products contain. Some states

absolutely prohibit the sale of dangerous drugs except on the prescription of a licensed physician. Another example of prohibitive regulation is the amendment to the Constitution, stopping the legal sale and manufacture of intoxicating liquors.

273. The public educates itself. The greatest enemy of the public is its own ignorance. New facts and new problems arise every day. It is impossible to teach in the schools all that the children will need to know, and it is certainly impossible to tell in advance about discoveries that are still to be made. Every progressive community, whether it be a city, a state, or a nation, seeks to *increase* knowledge and to *spread* it among its members as quickly as possible.

In every large city the health department has a staff of men and women whose business it is to make investigations on special aspects of local health problems. They study the water supply, the milk supply, the markets, the sewerage system, and the disposal of garbage. They conduct experiments for the purpose of increasing the accuracy or shortening the time of diagnosis, for in some cases a few hours may be of great significance. They experiment also for the purpose of improving materials and methods in the preparation of vaccines and serums, and they investigate the relative efficiency of different methods of fighting flies or ventilating factories or schoolhouses.

The state and local departments of health, the experiment stations, and the schools are continually at work increasing the protection of the public, and part of the protection consists in teaching all classes of people to make use of new ideas. The United States Public Health Service has supervision of marine hospitals and conducts special investigations on special diseases and on methods for preventing epidemics. In recent years there has been an increasing amount of coöperation between representatives and commissions from different countries, seeking to solve health problems on a world-wide scale.

In the work of all these agencies the distribution of information through bulletins, newspaper notices, pamphlets, lectures, conferences, posters, and other means constitutes an important element.

As we come to know more and more about the conditions affecting health, and as changes in our ways of living raise new problems, community activity will be extended farther and farther. For example, for some time to come the question of the school lunch will cause a great deal of discussion. We know that in the larger cities thousands of children come to school improperly or insufficiently nourished. The argument is made that the money spent in the effort to educate such children is all wasted, and that in order to save this money, and to insure the education of the children, it is necessary to put the children into condition to profit from the efforts of the teachers. This may mean that the school should supervise, or even provide means for, the feeding of children, at least so far as is necessary in order that they may do their school work effectively. Similar problems are arising in regard to the public provision of playgrounds, play apparatus, and even play teaching and direction. In some communities public dental clinics are supplied for all the children who need dental attention. To make use of knowledge may seem an expensive thing to undertake, but experience shows that nothing is more expensive or dangerous than ignorance. At any rate, it is through making use of such knowledge as we have that we can hope to control ourselves and our material surroundings to our best advantage.

COMMUNITY ACTIVITIES RELATED TO HEALTH

1. We cannot help influencing one another's health
    - Disposal of waste
        - Contamination of atmosphere
        - Contamination of water
        - Contamination of streets, soil, etc.
    - Throwing off disease germs
        - Spitting
        - Coughing
        - Sneezing
        - (From skin)
        - From clothes
    - Trying to make the most of our resources
        - Selling what may be injurious

2. We cannot always tell where real dangers lie
    - Unsuitable food
    - Spoiled food
    - Infected water
    - Infected milk
    - Unsafe dwellings
    - Germ-scattering neighbors
    - Unsuitable work places
    - Drugs, alcohol, etc.
    - Overwork
3. We cannot always manage to protect ourselves, even where we do know
    - Finding suitable supplies of food
    - Finding suitable water, milk, etc.
    - Obtaining reliable drugs, vaccines, etc.
    - Bargaining for suitable homes
    - Bargaining for suitable working conditions, hours, adequate pay, etc.
4. We cannot find out what is safe or best by ourselves
    - Individual experience is limited
    - The experience of the family is also too limited
    - Research and investigation can be effectively conducted only by skilled experts working together
    - The results of discovery cannot reach every individual quickly enough
5. We must depend upon community agencies
    - Health concerns all people, not certain classes only
    - None of us are safe unless all of us are protected

QUESTIONS

1. What restrictions does the law of your community place upon freedom of buying and selling? Why?

2. What are the advantages of legal restrictions upon business? What are the disadvantages?

3. What commodities are sold in your town with labels telling the exact content or nature and amount of adulterants or preservatives?

4. What are the advantages of having labels give information regarding the contents of food, drugs, etc.? What are the disadvantages of such labels?

5. What ways are there of finding out whether various foods etc. are adulterated?

6. What ways are there of finding out whether drugs, patent medicines, etc., are injurious? whether they are useful? whether they are as represented?

7. What is the per capita consumption of water in your community? How does that compare with other communities of similar size? of different sizes? in other parts of the country?

8. What is the source of the water supply of your community? What methods are used for protecting it?

9. What are the advantages of a community water supply over an individual supply? What are the disadvantages?

10. Why is it necessary to have special regulations regarding milk? What regulations are there in your community?

11. What is meant by *certified* milk? by *inspected* milk?

12. What is there to show that public regulation of the milk supply is of benefit to the public? to the producer? to the dealer?

13. What methods of milk inspection are used in your community? of dairy inspection? of testing milk as to quality? of testing milk as to bacteria?

14. What is the meaning of the violet-ink-stamp mark on meat at the butcher's, reading "U. S. Inspected and Passed"?

15. What are the advantages of placing meat, eggs, fish, etc., in cold storage? in any kind of storage? What are the disadvantages?

16. What provisions are there in your community for making sure that only fit food goes into storage? that only fit food is distributed from storage?

17. What does your community gain from supervision of food markets? What kind of supervision is it? What does it try to gain?

18. What method of waste and sewage disposal is used in your community? What are the chief advantages of this system? What are the chief disadvantages?

REFERENCE READINGS

HOUGH and SEDGWICK. The Human Mechanism, chap. xxxi, Public Health; chap. xxxiv, Public Supplies; chap. xxxv, Traveling and Public Places; chap. xxxvi, Public Protection.

United States Department of Agriculture (Office of Secretary). *Circular 21*, Foods and Drugs Act.

United States Department of Agriculture. Yearbook for 1916. Reprint 714, Meat Inspection Service.

United States Department of Agriculture. Regulations governing Meat Inspection.

United States Department of Agriculture. *Bulletin 585*, Guide for Formulating Milk Ordinances.

United States Department of Agriculture. *Circular 276*, Inspection of Milk Supplies.

Public Health Reprint 192, Bacteriological Standards for Milk.

Public Health Reprint 504, Treatment of Sewage for Single Houses and Small Communities.

Public Health Reprint 385, Laundries and the Public Health.

Public Health Reprint 821, Changes in a Small Town brought about by a Health Officer.

Public Health Reprint 827, Progress in Health Conservation during the Past Fifty Years.

CHAPTER XXXV

THE HOME IN RELATION TO HEALTH

Questions. **1.** If most people are brought up in homes, why must home-making be taught in schools and colleges? **2.** What makes a good location for a home? **3.** What makes some cities more desirable to live in than others? **4.** Is it better to live in the city than in the country? **5.** What should be taken into account when building a home? when renting?

6. What can be done in the home to make its people healthier? **7.** What can the home do for people's health better than the school can? better than public officials can? better than the individual can? **8.** How does the character of the home limit the welfare of the community? **9.** How does the character of the community limit the welfare of the home?

274. The importance of the home. Most people are born at home and most people die at home. It is the place where we get our first impressions of this world, and where we become acquainted with human beings, including ourselves. It is where we get our first lessons in the management of our bodies and of our environment, and in making the most of our resources. It is also the place where most people eat most of their meals, do most of their sleeping, and find most of their comfort. From every point of view, whatever happens in the home has a decided bearing upon our health and welfare; the health and happiness of a people depend directly upon the character of its homes. It is true, of course, that the home is not the only thing that influences health and happiness. Men and women with perfectly good homes can get into trouble or become ill, and people with rather poor homes manage to thrive to an old age.

275. The location of a home. A hundred years ago almost every family in this country lived in a separate house, and most people lived on farms or in villages. At the present time more than half our population is in towns or cities, and in the cities

an increasing proportion of the population live in apartments or tenements—that is, in houses built for two or more homes.

In cities most people have no choice as to where they are going to live, or very little choice. The location of a home is determined by the location of the industry or office in which one can find employment; or it is determined by the lines of transportation or by the amount of money one can afford to spend for renting a dwelling place. In most cities most of the people are exposed to one or more of the disagreeable by-products of industry and commerce—dirt, dust and fumes, smoke, odors, and noise; and until quite recently most of those who built tenement houses for other people's dwellings paid no attention whatever to the beauty of the structures or of the surroundings.

Where people have larger incomes, they take into account light and air, the nearness of parks and playgrounds, the nearness of good schools, attractive outlook, and beautiful surroundings. They try to get enough space to avoid overcrowding in bedrooms, and to assure opportunities for recreation and rest at home. It is true that these conditions are not always considered by those who build houses and cities or by those who are responsible for the regulation of building; still, more and more people are finding out the advantages of suitable homes and are making efforts to improve conditions in their own communities and to raise standards for all communities.

In the country and in villages, air and light usually take care of themselves; yet there are many houses in the rural parts of this country that seem to have been built by people who knew nothing at all about the importance of air and light. Many people keep their windows closed all the time, either through ignorance or for fear of "drafts" or "night air." Many keep their shades drawn to exclude the light, for fear of fading the carpets or wall paper. In many regions little attention has been given to the location of the house on the most favorable site for drainage, protection from winds, and the water supply.

276. The dwelling. It goes without saying that roofs should be waterproof and cellars dry. Heating arrangements should be

sufficient to supply all the heat needed on the coldest days, and yet subject to easy regulation, and they should be of a kind that assists in the ventilation. Hot-air furnaces and hot-water systems are most satisfactory in most cases. Floors and ceilings should be smooth and solid, without cracks in which dust and vermin may gather, and these as well as the walls should be finished to permit frequent cleaning. The arrangement of rooms and hallways must be planned to avoid dark corners or passageways, and dangerous steps, and to reduce the amount of work needed to keep things in order and clean. The kitchen especially needs to be carefully planned to save work and to insure cleanliness.

In the course of time the advantages of town and country housing will be available to city dwellers, as well as city comforts to rural dwellers. Many plans are being developed to separate the industries and business of a city from the residence portions, so that all the people may have an opportunity to live in suitable homes.

277. Cleanliness and sanitation. It is not often that the visible filth about a house is a menace to health. At the same time, visible filth indicates neglect, and neglect gives opportunity for vermin to multiply and for microbes to spread. To keep everything about a home spick and span means often to prevent sickness: it means often to prevent pus formation or festering after a slight cut or scratch; it means more pleasant surroundings for everybody, and so is an aid to mental health; and it means getting children into the habit of demanding cleanliness and maintaining cleanliness.

The amount of water used by a people may almost be taken as an index of its civilization. Every home, whether in the city or in the country, should have an abundance of running water. Where modern plumbing is installed in country houses, merely as a matter of convenience, the health of the people improves. In larger cities there is a large and measurable difference between the health in districts which have running water in all the homes and that in districts which have not; not only is

more water used in the former for cleaning purposes but the removal of bodily and household wastes is simplified. The presence of modern toilet facilities makes it easier to establish regular habits for the evacuation of the bowels, and connection with the sewage system makes it more likely that the organic wastes of the household will be entirely removed. Of course the water should be free from the contamination of sewage or other dangerous refuse.

The removal of garbage is an important problem of every home, not because it "breeds disease germs" (for it does not), but because it breeds flies and other vermin, and because its decay yields offensive odors. It is economical in towns and in rural districts to save the garbage for the pigs and chickens. It is worth while, however, to keep the receptacles and yards in which the animals feed perfectly clean. Daily washing of the pans and troughs will prevent the breeding of vermin and will add to the health of the stock as well as to the health and comfort of the people. In cities the removal of garbage by systematic street collections, or its destruction in furnaces, is economical in the long run because of its bearing upon health.

278. Food and feeding. A large part of the dyspepsia which is so common in this country comes directly from the fact that many of the home-makers are not skilled cooks. A large part of the malnutrition from which an alarming proportion of all children suffer comes directly from the fact that home-makers have not learned the principles of nutrition. A large part of the communicable disease is transmitted by means of food or drink. The home not only should provide suitable food, well prepared and attractively served, but it should cultivate tastes for suitable food and proper ways of eating. This is much more than a matter of good table manners to show off to acquaintances or in public places. It is a matter of physical and mental health and decent living. It should be possible for everybody of ordinary intelligence to understand the principles of balanced diet, not merely from reading about it in a book but from actual experience with well-balanced meals; and it is very im-

portant for each one of us to learn enough about food to be able to order meals when away from home with the assurance that they will satisfy bodily needs as well as the appetite.

Since food naturally contains the *materials* necessary to maintain the life of bacteria, we can keep it from spoiling or decomposing only by placing it under *conditions* that are not favorable to the growth of these organisms. In practice we have the choice between keeping our food very hot or very cold. We are not, as a rule, ready to cook our food immediately; we therefore turn to low temperature as an aid in preserving food from the destructive action of bacteria. We must be careful, however, not to assume that well-preserved food from the refrigerator is necessarily free from injurious microbes. We can see that any organisms that may have been present before the food was cooled are still there and are still capable of growing and of multiplying when a suitable temperature is restored. It is also necessary to keep refrigerators perfectly clean and free from neglected food particles that may retain bacteria. This principle applies, of course, to all cupboards, pantries, lunch boxes, or other places in which food is kept temporarily or permanently.

279. Sleep and rest. We spend, on the average, a third of our lives in bed. We should therefore have comfortable beds, with suitable coverings, and quiet sleeping places, well ventilated and easily kept clean. It is not only a hardship but a real privation, so far as health is concerned, to have to sleep in crowded quarters, or in rooms that are littered with materials and tools related to the day's work or with all the apparatus for preparing and eating food. Of course we can put up with many discomforts and inconveniences, especially when we are young and full of energy; but from the point of view of the common welfare we should not accept as necessary or permanent the bad conditions in which so many families live.

Sleeping porches, window shelves, and other arrangements for outdoor sleeping became quite popular for a time, after it was discovered that an abundance of fresh air is an important condi-

tion in combating tuberculosis; but one should not feel aggrieved if he cannot have a sleeping porch, for it is quite possible to get sufficient air by sleeping at an open window or even by securing a good circulation of air through the room. A rather hard mattress, but one without lumps and irregularities, is best for everybody, even infants, to lie upon, and light woolen blankets are best for covers. In colder weather additional covering can be used. Feather beds are undesirable because they interfere with the free circulation of air about the body, because they are too soft, because they increase the chances of cultivating bedbugs, and because they are hard to keep clean.

Regular hours for sleeping are especially important for children. An infant, from his first day, should be trained to sleep at fixed hours; and as the child grows older and his waking hours increase, it is still well to have a fixed time for going to sleep. Many adults complain of sleeplessness or of being unable to go to sleep when they go to bed; but in very many cases the difficulty is largely one of bad habits. By letting our minds wander in reviewing the day's experiences, or in wishing or planning for the future, or in worrying about what cannot be helped, we not only lose valuable sleep but do our thinking or planning wastefully. Children need more sleep than adults, and one of the hardships involved in inadequate housing is the fact that children are obliged to stay up until the whole family is ready to retire. Young children are found to benefit greatly from an afternoon nap. The time they lose in sleep is more than made up by the keener enjoyment of their play for the rest of the day. There is no danger, as a rule, that children will sleep too much.

280. Health education. By the time a young person is old enough to go to high school or to work he should have learned all the important things he needs to know about taking care of his body and keeping it in good condition. The fact is, however, that most of the grown people in this country do not know these things, which they should have learned in childhood. There are two sets of reasons for this general ignorance: (1) There has been a great shifting of populations during the past two or three

generations—from one country to another, from rural districts to the cities, from one kind of occupation to another. As a result people have come into new environments, to which their old customs of preparing food, running a house, and managing their work and their free time are not fitted. (2) Many scientific discoveries have been made during this time, showing us better ways of doing things; but these new discoveries are naturally unknown to masses of people. Every home should teach the children the best that the grown people know, but it is also well for us to recognize that new discoveries are constantly being made; we should be prepared to change our older ways and make use of new science.

Sound habits regarding eating, cleanliness, emptying the bladder and the bowels, drinking water, rest, and sleep can be established early and will probably need little modification with the growth of knowledge.

One set of problems that arise from modern living can be largely met by the establishment of certain habits during childhood. These have to do with so-called accidents. By far the largest proportion of fires and of the accidents that cause injuries or death could be prevented if all of us made a point of considering "safety first." There are times, of course, when one should consider his own safety last—when it is necessary to meet a catastrophe, to save lives, or to prevent suffering; but "safety first" means the habitual use of common sense in avoiding unnecessary risks of all kinds, for others as well as for ourselves. Children can learn to "watch their steps" almost as soon as they learn to walk; they can learn safe ways to handle fire and combustibles; and they can learn to be careful with machinery, moving objects, and tools. Prevention of traffic accidents means caution on the part of pedestrians as well as of drivers. We must learn to stop and look to the right and to the left before crossing a roadway, just as we must learn still earlier not to step into a stair well or a hole. Many accidents arise from confusion. You may start to cross a street, then see a car approaching and step back. In stepping back you may either

get in the way of another vehicle or in the way of the one that startled you, for the driver, seeing you start across, turned to pass behind you. Confusion or panic is very often the chief cause of disaster in case of fire in a public place or in case of accident on a passenger boat. We can improve the construction of houses and ships, and we can provide better exits or fire escapes, quicker lifeboat tackle, and so on; but these things do not prevent people from losing their heads. Fire drills in schools and factories, learning to swim, and familiarity with the construction of buildings or ships all help. Aside from these things, however, each one of us needs to get the habit of looking about for the location of exits whenever we go into a theater, for example, and for the location of life preservers when we go aboard a boat. The constant habit of looking out for such things is most easily and surely acquired during childhood, and the opportunities for learning the principle are present in every home, as well as in the situations in which parents and children find themselves outside the home.

The handling of kerosene and gasoline, and even of illuminating gas, is always attended by danger. Not only may illuminating gas asphyxiate a person, when it displaces the air in the lungs, but in many cases it contains enough *carbon monoxid* to poison the body (see section 141). Kerosene and gasoline should never be drawn by candle or lamp light, and should *never* be used in the presence of an open flame or to encourage a poor fire in a stove. The danger of fire from gas comes from the fact that this substance forms an explosive mixture with air. The odor of gas should be a warning that some has escaped from the pipe or from an open burner. All flames should be immediately put out, and the search for the leak or open cock made; if an artificial light is necessary, use an electric light on a long cord, or an electric flash light.

Fire is so important in the life of man that its benefits have more than compensated for the destruction which it has caused. We need it so much that everybody should learn to handle it with perfect safety, whether in open fireplaces and bonfires or

in stoves and furnaces and in lamps and special torches. We need to learn both how to use it and how to protect ourselves from it, and we need to know what to do when it gets beyond control, for the danger to people and life is quite as great as the danger to property. The treatment of burns and wounds is included in another important branch of home education, that is, the subject of giving first aid in case of injury. Some reference has already been made to the treatment of bleeding, wounds, and scratches (section 155), and of drowning.

281. The home and the community. The health of a community depends to a certain degree upon the considerateness of each individual and upon the extent to which all coöperate—matters largely decided by what goes on in the home. Spitting, for example, in so far as it has anything to do with health, seldom hurts the person who does it, but most people will do in this respect very much as they learned to do as children. The same may be said of throwing things on the sidewalk or out of the window, where they may become a source of injury to other people. In many cases people mean to do the right thing but do not know just what is right. Thus parents often send off to school children who should be kept at home because the "slight cold" or "sore throat" may turn out to be diphtheria, which is passed on to other children. People sometimes break quarantine simply because they do not understand the importance to other people's children of the isolation of a germ carrier. Rules regarding vaccination, requests from the authorities to have the eyes or teeth examined, and similar efforts of health authorities to promote the welfare of individuals and of the group would have the hearty support of all if they only understood the reasons for such efforts. Education in regard to new discoveries is thus an important factor in family and community health.

282. Standards for homes. We have gradually developed standards for homes in this country and in other countries in which modern science is being applied, and we find it convenient and helpful to compare groups of homes as to the results they

produce. One of the best single tests of good homes in a community is found in the *infant death rate* (see page 358). It is usually expressed as the number of infant deaths per thousand births in a year. Thus, an infant death rate of 112 means that in one year that number of children under one year of age died for every thousand children born during the year.

The wide variation in the infant death rates of different communities is shown in the following table, which is selected to show the best records and the worst records for one year, 1923:

INFANT MORTALITY RATES FOR THE YEAR 1923 IN TWENTY SELECTED AMERICAN CITIES

(Total deaths under one year of age per 1000 births)

Best Records		Worst Records	
Pasadena, California	37.0	Kansas City, Kansas	97.0
Berkeley, California	41.0	Pittsburgh, Pennsylvania	98.0
Spokane, Washington	48.0	New Bedford, Massachusetts	105.0
Seattle, Washington	49.0	Richmond, Virginia	110.0
Portland, Oregon	53.0	San Antonio, Texas	127.0
Minneapolis, Minnesota	54.0	Pueblo, Colorado	132.0
San Francisco, California	58.0	Atlanta, Georgia	134.0
Oakland, California	63.0	Winston-Salem, North Carolina	142.0
Des Moines, Iowa	64.0	Charleston, South Carolina	150.0
St. Louis, Missouri	70.0	El Paso, Texas	169.0

These figures show that out of a given number of babies born in a certain time more than twice as many died during the first year in one city as in another city. Moreover, similar variations are found between the death rates in one district and the death rates in other districts of the same city. A baby, one might say, has a better chance of seeing his first birthday if he is born in one part of the city than he would have if born in a certain other part of the city. Now what is it that endangers babies' lives in one case or protects them in the other?

The best information that we now have on the subject shows that to a very great degree *the children that die in infancy could be saved*, because the excessive deaths result from conditions

that we can control. These conditions are sanitary homes, care of the mother before the child is born, expert service at the time of birth, and proper feeding and care of the child after birth (see Fig. 167). Of course it is important that the parents

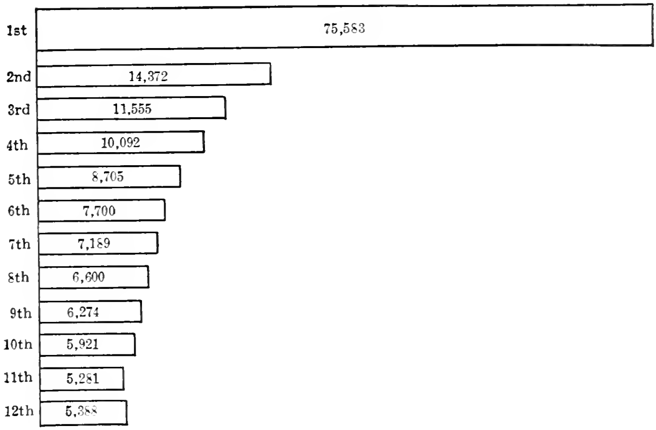


Fig. 167. Distribution of infant mortality during the first year

Out of the 164,660 babies in the United States who died during the first year after birth in 1916, over 75,000 died during the first month. The chief causes of death for this group were insufficient family income, diseases of the parents, poor health of the mother, unskilled assistance at birth, lack of suitable care immediately after birth. In other words, most of these deaths are preventable

be healthy to begin with, but it has been shown again and again that even in the case of unhealthy parents it is possible to care for the mother in such a way as to save the baby and have it grow up safely past the dangerous period.

THE HOME IN RELATION TO HEALTH

1. Importance of the home
    - Physical well-being and health
    - First education and character formation
    - Security and comfort
2. The home and its location
    - Changes in character of dwellings
        - Crowding of population into cities
        - Crowding of many homes into single buildings

New conditions resulting from industrial changes
  Contamination of air with dust, fumes, smoke, etc.
  Disagreeable odors
  Noises
Desirable physical conditions
  Light and air
  Nearness to parks and playgrounds, to schools, and to place of work
  Large rooms
  Clean surroundings
  Quiet surroundings
  Beautiful surroundings and outlook
  Drainage
  Adequate water supply
  Weatherproof walls and roof
  Suitable heating arrangements
  Dirt and vermin-proof floors, walls, and ceilings
City planning

3. Cleanliness and sanitation
  Relation of cleanliness to physical and mental health
  The cost of cleanliness
  The importance of water
    For bathing, washing clothes, etc.; for removing refuse
  Protection of water supply
    In the country; in the city
  Disposal of garbage
    Why important; methods
  Handling of food
    In relation to infection etc.; in relation to vermin
  Prevention of infections from a patient
    Disposal of discharges
    Fumigation and sterilization
    Cleaning of clothing, bedclothes, etc.

4. Food and feeding in the home
  Relation to nutrition and health of its members
  Relation to cultivation of tastes and manners
  Relation to education in food values
  Importance of careful marketing
  Importance of proper preparation, storage, and service
  Method of preserving from bacterial action

5. Sleep and rest
  Importance of suitable sleeping quarters
  Outdoor air for sleeping
  Suitable bedclothes
  Regular hours
  Good sleeping habits
  Afternoon nap
  Amount of sleep

6. Health education in the home
    - Why so many people do not know the best way to take care of themselves
        - Shifting of population and breaking up of old customs
        - Scientific discoveries
    - Importance of establishing sound habits early in life
        - Eating
        - Sleeping
        - Cleanliness
        - Habits of caution
    - Learning to handle dangerous material and objects
    - Learning to keep cool in emergencies
    - Principles of first aid
7. Home and community
    - Consideration for neighbors and others as affecting health
    - Coöperation with health authorities
        - Reporting
        - Quarantine
        - Vaccination
        - Examination by dentists, oculists, etc.
8. Infant mortality a measure of the quality of homes
    - Variations in infant mortality
    - Chief causes of death among babies
        - Low income of family
        - Health condition of mother
        - Unskilled assistance at time of birth
        - Care of mother and of infant during first few weeks
        - Disease in parents

QUESTIONS

1. How do homes in the United States differ from those that immigrants from various countries knew when they were children?

2. How do homes of today differ from homes of fifty years ago?

3. What changes have made work in the home easier than it used to be? more difficult?

4. What are the advantages of separate houses over apartments? What are the disadvantages?

5. What can be done to insure cleanliness in a home without bathtubs? without hot-water supply? without running water?

6. How can you make sure that each individual uses his own towel at home? Is it worth while to do so? Why?

7. What are the advantages of having sleeping quarters separate from living quarters? What are the disadvantages?

8. How can the home water supply be protected in the country?

9. How can house waste, garbage, etc. be kept from injuring health?

10. What are the advantages of periodic visits to the dentist? What are the disadvantages?

11. How can young children be made to keep well with the least looking after?

12. How can people with different customs and habits be made to coöperate in maintaining the health and safety of the community?

13. What is the infant death rate in your community? How can it be reduced?

REFERENCE READINGS

CONN, H. W. Bacteria, Yeasts, and Molds in the Home, chap. iv, Decay of Fruit; chap. x, Preservation of Food; various chapters for special reports.

HOUGH and SEDGWICK. The Human Mechanism, chap. xxvii, The House; chap. xxviii, The Warming and Lighting of the House; chap. xxx, Water Supply etc.

Public Health Bulletin 70, Good Water for Farmhouses.

Farmers' Bulletin 1227, Sewage and Sewerage of Farmhouses.

Farmers' Bulletin 1180, House Cleaning made Easier.

Farmers' Bulletin 1374, Care of Food in the House.

Farmers' Bulletin 851, The House Fly.

Farmers' Bulletin 658, Cockroaches.

Public Health Reprint 626, The Bedbug.

United States Bureau of Mines. Technical Paper 199, Five Ways of saving Fuel in Heating Houses.

United States Bureau of Standards. Safety for the Household.

Public Health Miscellaneous Publications 17, Prevention of Disease and Care of the Sick; How to keep Well, First Aid, etc.

CHAPTER XXXVI

INDUSTRIAL PROBLEMS OF HEALTH

Questions. **1.** Do people live longer in civilized countries or in uncivilized countries? What conditions make the difference? **2.** What conditions in modern life are unfavorable to health? What conditions are favorable? **3.** What kinds of occupations are dangerous? Why? Why do people enter dangerous occupations? **4.** Can dangerous occupations be made safe? **5.** How can accidents be prevented? **6.** Why do the laws interfere more with some kinds of business than with others?

283. Changing conditions of work and life. With the growth of industry it has become easier to produce the necessities and conveniences and luxuries of life. As a result the standards of living have been steadily rising in all industrial countries for a century and a half. In more recent times it has been possible to measure the improvement in part by a study of the health conditions and the death rates. If we compare the sickness and death rates of poorer communities or countries with those of more prosperous communities or countries, we find that, on the average, the poorer people have more sickness and die younger. If we compare the health and mortality of earlier periods with later periods, we find improvement. Of course this improvement is not wholly due to increase in the productivity of industry, but it is partly due to that. The men and women whose work makes living conditions better are themselves often suffering from bad working conditions. Some occupations are strikingly dangerous, involving serious accidents. Among these are marine service, iron and steel manufacture, chemical manufacture, and work in compressed air. Other occupations are dangerous to health, although they are not classified as hazardous or as involving great risk of accident. The dangers in such occupations arise from the special materials used or from the

conditions under which the work is carried on. In the making of chinaware and pottery, for example, there may be danger of lead poisoning; in clothing manufacture danger may arise from badly ventilated workrooms. As soon as we recognize that *the objectionable conditions are not necessary*, we must take steps to find remedies; and as science has helped to improve conditions of living and to increase production, it can be made to improve conditions of working.

284. Physical conditions. In many industries it is impossible to prevent the formation of dirt of various kinds. Whenever this has an effect upon the physical health it should be removed from the immediate vicinity of the workers as quickly as possible. In any case there should be facilities for thorough washing before lunch is eaten, and at the close of the day's work. Modern stores and factories provide lockers in which workers may keep their street clothes, as well as washing facilities (including in some cases shower baths), so that workers may be clean and self-respecting when they leave the works. The supply of suitable drinking water and of toilets is also essential for keeping workers in good health. There should be places for eating lunch separate from the working rooms, even though the latter are clean, light, and airy. Whenever it is possible to do so, workers should get away from the office or factory entirely during the lunch period, to get as complete a change of air and surroundings as the available time will permit.

In many states the laws prescribe a minimum air space for each worker in industrial plants. In most cases this space is four hundred cubic feet, exclusive of machinery or furniture. This amount of space makes it possible to change the air fast enough to remove the heat and moisture given off by the body, and the organic matter given off by the lungs, without causing a draft.

The temperature of the air has an important bearing on the worker's health (see page 168). In some industries the processes themselves call for a higher or a lower temperature than is best for human beings. Where the character of the work requires a low temperature, as in packing houses, refrigerating plants, and

some chemical works, the body should be provided with warmer clothing and the humidity of the atmosphere may be higher. In mines, bakeries, tunnels, foundries, rolling mills, or other places where the temperature has to be high, workers should wear light clothing or even be stripped to the waist. In such cases humidity must be kept low and the air must be in constant circulation, so as to increase the evaporation from the skin.

Another source of injury to the welfare of workers is *noise.* Most people endure a great deal of noise day after day without being aware that they are disturbed by it; but it is bound to have an irritating effect and "get on the nerves" sooner or later. Excessive noise is the cause of a large proportion of difficulty in hearing.

285. Gases and fumes. In many industries poisonous gases and fumes are produced. These either "eat away" the delicate linings of the lungs or are absorbed and injure the whole system. Most acid fumes act in the former way. Alcohols used in varnishes, phosphorus fumes, lead fumes, benzene, and other fumes poison the body. It is for these reasons that the manufacture of white-phosphorus matches has been entirely prohibited by law in this country, and that the use of wood alcohol in varnishes and shellacs has been prohibited in some states and cities.

Where the work produces fumes or gases, these must be removed by flues connected with exhaust fans. No person should work regularly in any establishment that permits irritating or dangerous fumes to enter the air breathed in the shop. In laundries and garages, as well as in other places, men and women have been poisoned by *carbon monoxid* (see section 141).

286. Dust. In many occupations the worker is constantly exposed to dust which may be injurious in several ways.

1. It may form a crust over part of the lung lining, thus reducing the actual breathing surface and at the same time weakening the resistance of the cells to disease microbes. Examples are coal dust and the fluff from the fibers used in spinning and weaving.

2. Dust consisting of hard, sharp particles may scratch the delicate linings of the air sacs, exposing them to the entrance of disease microbes. Examples are metal and stone dust and fine sand, produced in industries in which metals are ground and polished, in which sand blasts are used, and in which the chipping of metal or stone is carried on.

3. Dust may carry with it disease germs of various kinds. Street and house dusts are the most common source of this kind of danger.

A list of the most common occupations in which the danger from dust is an important factor is given below. It is possible in most of the industries to reduce the danger from dust almost to zero, if we take the trouble to do so.

SOME COMMON OCCUPATIONS IN WHICH DUST IS A SERIOUS MENACE TO THE WORKERS

Mining
Crushing of metals and minerals
Sifting of metals
Molding and core-making
Grinding and polishing
Brass-working
Tool-making
File-cutting
Marble-cutting
Stone-working
Glass-working
Cement-working
Pottery and other earthenware industries
Plastering and paper-hanging
Diamond-cutting
Engraving
Jewelry-making
Grain-handling
Flour industry
Starch-refining
Baking and confectionery work
Tobacco-working
Cotton-textile industry
Flax and linen industries
Woolen and worsted manufacture
Silk industry
Spinning
Weaving
Hosiery and knitting industries
Lace-making
Hat-making
Hemp and cordage industries
Jute and jute-goods industries
Shoddy manufacture
Rag-picking and rag-working
Wood-turning and wood-carving
Cabinetmaking
Upholstery and mattress-making
Brush-making
Paper-making
Printing industry
Lithographing
Street-cleaning

In polishing furniture powdered pumice stone and oil can be used instead of sandpaper.

In some dusty processes the machinery and the material are inclosed in such a way as to prevent the escape of dust into the air breathed by the workers — for example, in flour mills, in the crushing of ores and minerals, and in the polishing of small metal objects.

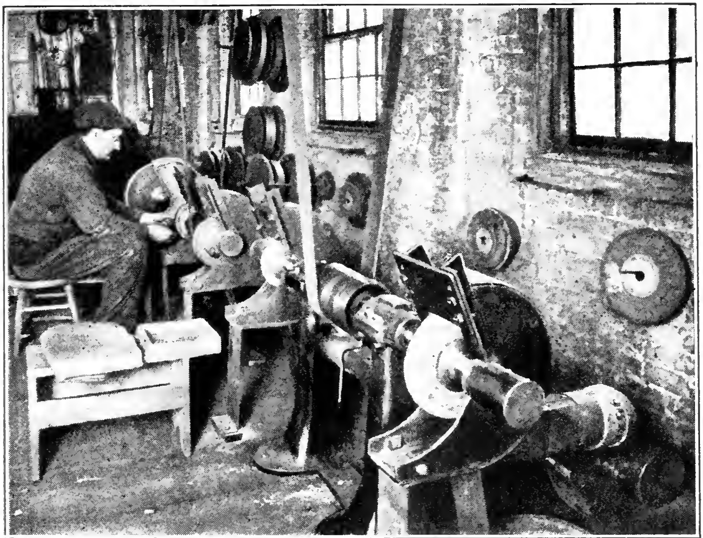


Fig. 168. Dust and safety hood

In polishing metal goods this hood protects the worker from dust and, in case the wheel bursts, from flying particles. (From a photograph furnished by the New Jersey Department of Labor)

In grinding paints or metals it is possible in many cases to use a wet process, in which water or oil holds down the dust particles resulting from the grinding.

Where it is not practicable to keep down the dust in the process, special hoods connected with exhaust pipes are placed over grinding wheels, over rotary saw blades, over polishing wheels, and so on, to draw the dust away from the point at which it is produced (Fig. 168).

In many workrooms it is necessary for the individual worker to wear an air filter over his mouth and nose. This respirator consists of a canvas cup holding a wet sponge or cloth (see Fig. 169) through which the breathed air must pass, leaving the dust behind. The gas masks worn by soldiers during the World

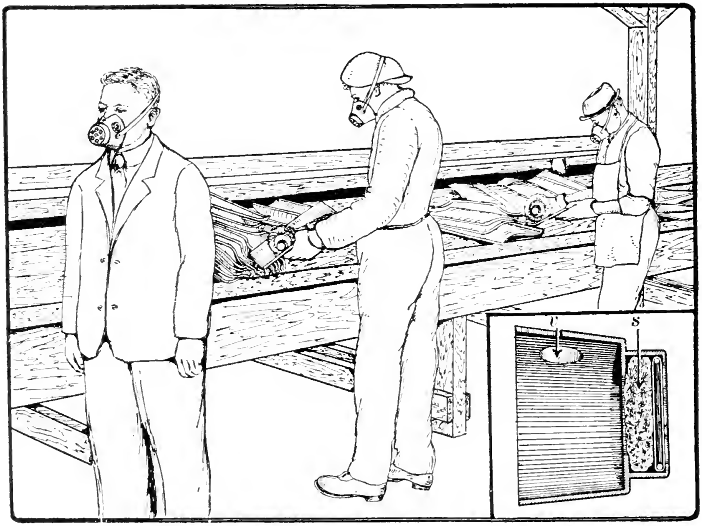


Fig. 169. Respirator

In many industrial processes it is impracticable to remove the dust by mechanical means. The respirator is worn by the worker to filter the dust out of the air which he breathes. The sectional view shows the valve, *v*, and the sponge, *s*, through which the air is filtered. (From photograph lent by the American Museum of Safety)

War, by firemen, and sometimes by miners usually carry, in place of a *mechanical* filter, a *chemical* preparation to absorb or to counteract the gas from which they protect the wearer.

287. Fatigue. We can feel restored by sleep or rest without taking additional food. Experiments show that the human body or any other animal organism behaves, when fatigued, as though some special substance in the cells prevented their full activity. Fatigue has therefore been considered a *poisoning*, which

is supposed to result from the by-products of cell metabolism and is not the same as exhaustion from lack of nourishment.

This view is borne out by two sets of facts, illustrated by these experiments: (1) A dog that has had plenty of rest has injected into his veins some blood from another dog that has been kept running until he has become tired. The first dog at once shows all the signs of fatigue. (2) A muscle taken from the hind leg of a frog is kept working until it fails to respond to further stimulation. The muscle is then washed in salt water (which would remove certain classes of poison from the cells), and it is at once restored to its original vigor.

One of the important things about fatigue is the *pace*. If one works too fast, the fatigue poisons cannot be carried off by the blood as fast as they are formed in the cells. By working more slowly one can continue to work indefinitely without fatigue, although one may need to stop for other reasons.

Since all working cells may become fatigued, a man or a woman engaged at some task may show signs of fatigue out of proportion to the apparent exertion or performance. One is worried, for example, or eager to make a record, or anxious about earning enough money. He then uses up a large amount of energy for "work" that does not show in the product, and he also accumulates fatigue poisons. In factories the machinery often controls the pace, and high speed becomes a serious matter, especially if connected with long hours.

The dangers from getting too tired day after day are

1. The tired worker causes more accidents.

2. The tired worker, having no time to catch up between one day's work and the next, falls steadily behind physiologically, and so becomes less capable of resisting injury or infection, less capable of enjoying his leisure, and less able to take part in his duties as citizen or as member of a family.

Fatigue poisons affect the gland cells as well as the nerve and muscle cells; hence the frequent indigestion following meals eaten when the body is fatigued. Fatigue poisons also affect the white corpuscles, and the chemical activity of the cells generally, so that a person when fatigued is more likely to catch

colds and other infections. For these reasons sufficient sleep is one of the prime necessities of healthful and efficient and happy living. People whose daily tasks are too long are most likely to get their fun in time taken from sleep. It is during sleep that the working and growing cells can make up for the losses resulting from the day's work. It is also during sleep that excretion can catch up with the day's accumulation of wastes.

288. Hours of work. There was a time when mill workers had to be at their tasks sixteen and eighteen and even more hours a day. They got along somehow, but they died young. The injurious effects of long working days upon the worker are coming to be recognized by society at large as well as by the workers most concerned. The workers are constantly demanding a shorter and shorter work day, and legislation is steadily making the legal work day shorter and shorter.

Most of the states now have laws limiting hours of labor, either in special occupations and industries or in general, and many cities limit the hours on public works. The public demand for shorter hours rests chiefly on two considerations:

1. The human stock must be preserved from the evil effects of overwork, and the ordinary methods of bargaining about hours and wages cannot be relied upon to secure what is fair for the workers. This is especially true in certain dangerous industries, like coke-making or work in compressed air.

2. In certain occupations the fatigue of the worker is a direct menace to the public. This is especially true in such occupations as railroading of all kinds, elevator operating, work on boats and ferries, telegraph and telephone operating, and so on.

The human side of the problem was recognized in legislation as long ago as 1913, when Oregon declared that "no person shall be hired nor permitted to work for wages, under any conditions or terms, for longer hours or days of service than is consistent with his health and physical well-being and ability to promote the general welfare by his increasing usefulness as a healthy and intelligent citizen." This law sees in the worker's health a necessary part of good citizenship and progressive civilization.

At the outbreak of the World War a sudden increase in the demand for all sorts of supplies and munitions led the managers of industry to increase the number of hours of work and to speed up the workers in the factories. In England it was soon found, however, that this plan, instead of increasing production, actually diminished it, and resulted in a great deal of ill health and physical breakdown among the workers. A commission appointed to study the health of munition workers found: (1) Increasing the number of hours of work is bad for the health of the workers and for the quality of their work. (2) Working day after day without weekly rest days is bad for the health of the workers and for the quality of production.

As a result of this and similar investigations many factories in Europe and in this country have established new methods for determining the speed at which work should be done. The day's work is divided into short shifts, or "tricks," which permit production to be increased while the fatigue and accidents are diminished and the health of the workers is improved.

289. Mental-health conditions. One of the most important factors in the poor health of workers is irregularity of employment. This produces very marked physical effects, because it is usually accompanied by low income, and therefore inadequate nourishment, unsuitable housing and clothing, lack of proper recreation, and so on. Moreover, irregularity of employment leads to *worry*, more often than any other one thing connected with work. This worry leads to bad mental habits, irritability, nervousness or mental strain, and loss of sleep. On the physical side it shows itself in indigestion and general weakening of the whole system. There are other sources of worry besides irregularity of employment; but whatever the reasons may be in any particular case, it is bad for the health of the body, and it may be considered in itself an unhealthy condition of mind.

Closely related to worry, and in many ways similar in its effects, is *fear*. Such anxieties result not so much from the conditions in any particular occupation or establishment as from the general working and living conditions in a given industry or

community. For example, in a factory town where people are often out of work, or where accidents are frequent, or where most people never have a chance to become skilled workers, we are likely to find a combination of poverty and this kind of anxiety.

A great deal of unhappiness at work, and consequently of bodily inefficiency and poor workmanship, comes from small annoyances of various kinds, such as the rudeness or boisterousness of fellow workers, the harshness or inconsiderateness of the foreman, irritating noises, the monotony of the work, offensive odors, bad lighting, and unsatisfactory toilet arrangements. The worker as a rule is unaware of what annoys him, or he dislikes to complain. It is therefore seldom that difficulties are discovered by those who could remedy them, and a worker remains until he can stand it no longer or until an outbreak of bad temper leads to a discharge.

A very important and frequent source of mental disturbance is the lack of harmony between the worker and the manager or between the worker and the character of the work. This is a serious matter both for production and for health and happiness. Yet it is very difficult to make suitable adjustments in every case, and sometimes it is not at all possible. Nor is it always possible to place the responsibility for the bad conditions, or rather bad relations. If a worker cannot get along with the foreman or with his fellow worker, it may not be the fault of either person; each one may be all right in his own way, but they simply do not belong together. The same thing may be said where a person is not getting along well with a particular kind of work.

290. Accidents. We usually think of an accident as something that happens out of the ordinary course, for reasons entirely beyond our control. A closer study shows that at least a very large proportion of accidents can be prevented.

In many kinds of industry and in transportation there had been a steady increase in danger from accidents until, some years ago, engineers, insurance experts, health workers, and managers were forced to take notice of the bad conditions and

began to look into ways of preventing or reducing the losses due to accidents (see Fig. 170). Now the prevention of accidents has become a recognized part of the business of managing industry. The accident rate is different in different occupations (see Fig. 171) and indicates in many cases an almost inhuman disregard for the safety and welfare of men and women.

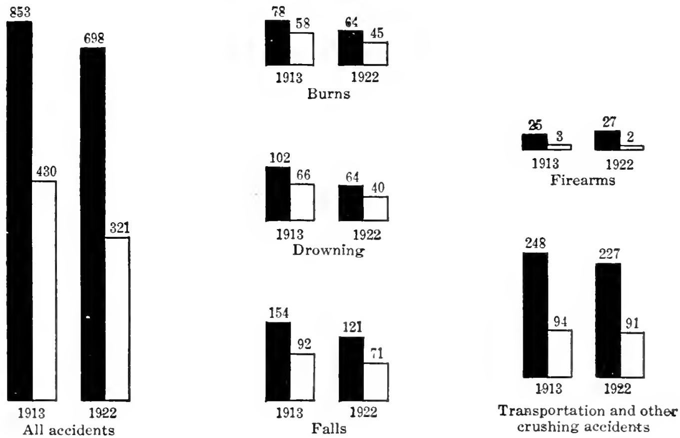


Fig. 170. Accidents in the United States and in England and Wales

In this country all kinds of accidents, including industrial accidents, are more numerous in proportion to the population than they are in other countries. The black columns correspond to the fatal accidents per million of population in this country; the white columns to the fatal accidents per million of population in England and Wales. While we see great improvements in both countries during ten years, the improvement is greater abroad

The causes of accidents are numerous, so that it is not possible in every case to attribute the occurrence to a particular person's carelessness. First of all, very few of those in charge of industry have in the past taken special pains to watch every new method, every new machine, to see whether its use is perfectly safe for the worker; and, on the other hand, most workers are either too ignorant to ask about the dangers or too anxious to get the jobs to ask any questions at all. As a result heavy and intricate machinery has developed rapidly until it has got

beyond control, and complex processes, often using dangerous materials, have gradually spread through industries without anyone's being responsible for their regulation. Moving parts, revolving or hurtling through the air rapidly, do considerable damage when they come in contact with any part of the body. Belts catch at a bit of clothing or a wisp of hair set fluttering by

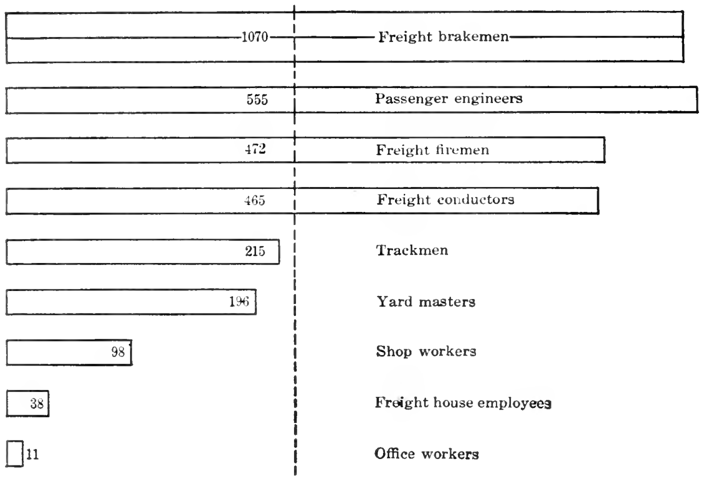


Fig. 171. Fatal accidents in various railroad occupations

In one year the proportion of fatal accidents among different classes of railway employees varied from 11 per 100,000 to more than 1100 (not shown in the diagram). The dotted line represents the rate for the whole industry in 1910, that is, 225 per 100,000. This means that in the railroad business some of the occupations are a hundred times as dangerous as others

a gust of air; slippery floors, unguarded openings, obstructions, worn cables or bolts that give way, and dozens of other things add to the dangers; and the noise and intensity of the work make it almost impossible for the worker to be on his guard. Most of these conditions are dangerous largely because of the great speed imposed by the machinery, or by the driving foreman, or by piece-work payment. This plan of pay is designed to make people work faster, and does actually make them work faster, but often with very bad results to their health and welfare.

Fatigue and strain increase the accident rate. This is shown by the variation in the number of accidents from hour to hour during the day (see Fig. 172). Undernourishment, poor ventilation, defective illumination, and alcoholism also contribute their share to the high accident rate. Reckless workers expose themselves to dangers. On the other hand, some workers

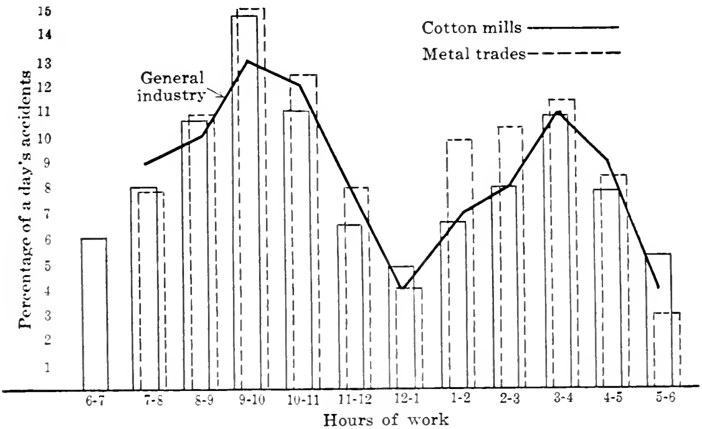


Fig. 172. Variation in the percentages of accidents hour by hour

In industry in general the number of accidents per hour increases steadily from the time work starts in the morning until past the middle of the forenoon; then the number declines to a minimum between twelve and one. In the afternoon again, each hour sees an increase in the number of accidents until about four o'clock, when there is a decline to the end of the day's work. This is shown by the shape of the solid line in the figure. The same general facts are found to hold for such different industries as cotton manufacture (the solid columns) and metal trades (the columns with dotted lines). A very important factor in bringing about this condition is the fatigue of the worker. By introducing a short rest period in the middle of the forenoon and another in the middle of the afternoon many industries have succeeded in greatly reducing accidents, errors, and the spoiling of material

fail to consider the possible results *to others* of careless workmanship or habits, as in setting up scaffolding, tightening supports, turning off electric current or power, leaving tools or other objects out of place, and so on. It is the workers who cause accidents, and it is the workers who suffer, but it is not always the same workers.

291. First aid. Under the most favorable conditions it is impossible to eliminate *all* accidents. Even in an office or a school, where the dangers are not great, accidents will happen, as the proverb says of the best-regulated families. People fall through a misstep, they cut and bruise themselves, something breaks loose and strikes a person, and so on. Every plant that has a considerable number of people working in it should be prepared to deal with minor accidents until medical aid can be obtained. Every modern industrial plant is indeed equipped with first-aid appliances and has always at call a nurse or some other person trained to meet emergencies that involve bodily injury. In larger plants, especially in those which employ heavy machinery or materials or high-power appliances, and in which danger from accidents is accordingly greater, there are well-equipped dispensaries and hospitals.

292. Women and children in industry. Within the last few generations the whole character of industry has changed radically. As a result (1) many industrial occupations requiring comparatively little skill or physical strength became open to women and children; (2) many products formerly made at home came to be more cheaply made in the factories. Children, kept for long hours at monotonous tasks, grew up into ignorant and incompetent adults, worth no more as wage-earners than children. Women had to get such work as they could to help out in the family income. Children and homes were neglected, and general deterioration of the working population gradually set in. This condition became alarming in England, and royal commissions appointed to study the problem recommended various improvements; but their recommendations met with stubborn resistance. On the one hand, employers objected to the interference of government in what they considered their private business. On the other hand, many workers felt that regulation was also an interference with their liberty, their right to work wherever they liked, as long hours as they liked, and so on. Steadily, however, improvements were brought about, partly through legislation, partly

through the demands of workers themselves, and partly through experiments by forward-looking employers and managers who discovered that it was really more profitable to shorten hours, to clean up workshops, to have better light and ventilation, to insure enough food for workers, and so on. In more recent times children have been receiving an ever-increasing amount of protection from the state, because it began to be recognized that unless children get a certain amount of education, and unless their health is protected during their growing years, they will grow up to be poor citizens as well as poor workers and poor parents. There are important physiological and mental differences between men and women. It is found, for example, that work in industries in which there is lead dust or lead vapors has a distinct effect upon women that interferes with their becoming healthy mothers. In other industries the mere fact of fatigue may affect prospective mothers more than it does other women or men. Many students of the subject long ago came to the conclusion that it is necessary to restrict the work of women in industry. The health of children is so important to the state that we cannot allow it to be jeopardized by the unwholesome work of mothers and prospective mothers and home-makers. This, however, should not influence women's political rights, for example, or the opportunity to enter the professions or to manage business.

293. Occupational diseases. The growth of industry has meant an increasing division of labor. This has meant increasing specialization. As a consequence each one of us becomes obliged to overemphasize by repetition a small number of activities. One person does a great deal of walking in his daily work; another sits in one place most of the time. One uses his arms in large movements nearly all day long; another moves hardly more than his fingers. This one uses his eyes to the exclusion of other sense organs, while that one uses the tips of his fingers all day long to pass on the quality of furs or textiles. As a result many workers become unevenly developed or acquire special marks of their trade. There is curvature of the spine from

awkward standing or sitting; there is overdevelopment of the shoulders with corresponding underdevelopment of other parts; there are calluses and twisted fingers and flat feet. The boiler-maker suffers in his ears, the granite-cutter in his lungs, the preacher in his throat, and so on. The tired accountant sees figures jumping all around until his head swims, or he automatically adds all the numbers that he sees or hears. There are lawyers who come to be incapable of considering any problem that comes up except in relation to statutes or court actions.

Workers in compressed-air chambers suffer from the bends, a very painful condition resulting from going too rapidly from a high-pressure atmosphere to a low pressure; workers in animal hair and hides are exposed to infection by anthrax; miners and other workers in the ground may be infected with hookworm disease. Glass-blowers, furnace-workers, electricians, photographers, and others who work with strong light are in danger of receiving serious eye injuries.

It is well to plan recreation and exercise of a kind that will balance or counteract the undesirable effects of conditions of work. Many physical hazards and infections can be avoided by suitable guards, garments, shields, and so on. It should be possible to get many of the advantages of a high subdivision of labor without suffering from all the disadvantages.

INDUSTRIAL PROBLEMS OF HEALTH

1. Changing conditions of work and life
    - Increasing production raises standard of living
    - Improved living shows in better health and longer life
    - Working conditions not always favorable to health
    - Increase in accident rate
2. Physical conditions
    - Cleanliness
        - Removal of waste
        - Washing facilities
        - Lockers for clothes
    - Ventilation
    - Lighting
    - Drinking water
    - Toilet rooms
    - Lunch room
    - Temperature
    - Noise

3. Gases and fumes
    - Effects
        - Trying to lungs
        - Poisonous to whole system
    - Removal
    - Prevention
4. Dust
    - Occupations in which dust is a menace
    - Kinds and effects
        - Cover lung lining
        - Scratch lining
        - Infection
    - Reducing the danger
        - Change operations
        - Draw off dust
        - Respirators
5. Fatigue
    - Contrasted with nutritional exhaustion
    - Evidence of poisonous effect
    - Relation of pace to removal of wastes
    - Wasteful management of work
    - Dangers of excessive fatigue
        - Accidents increase
        - Organism deteriorates
    - Importance of rest and sleep
6. Hours of work
    - Relation to health
    - Public regulation
        - To preserve the vigor of the race
        - To protect the public
    - Relation to citizenship
    - Relation to production
    - Days of rest
7. Mental-health conditions
    - Effect of irregularity of employment
        - On physical well-being
        - On mental state (worry)
    - Effects of fears
    - Annoyances of various kinds
    - Importance of harmony
        - Between workers
        - Between worker and manager
        - Between worker and work
8. Accidents
    - More numerous in the United States than in other countries
    - Proportion of fatalities more numerous
    - Accidents are preventable in great degree
    - Causes
        - Heavy and intricate machinery
        - Complex processes
        - Dangerous materials
        - Exposed belts and other moving parts
        - Slippery floors
        - Unguarded openings
        - Worn or loose parts
        - Dark and obstructed passages
        - High speed of work
        - Overwork
        - Poor physical conditions in plant
        - Poor home conditions
        - Individual carelessness
        - Inconsiderateness

Prevention
  Removal of dangerous conditions
  Better management
  Education of workers

9. First aid in industries
   Appliances
   Nurse
   Doctor
   Infirmary etc.

10. Women and children in industry
    Women and children have always worked
    Why there is a problem today
      Work in factories has increased
      Suitable work in homes has diminished
    Danger to education of children
    Neglect of home
    Deterioration of people
    Reasons for government protection
      Of children; of mothers; of all women

11. Occupational diseases
    Effects of division of labor
      Simplifying individual work
      Emphasizing specialized activity
      Enforcing unbalanced development
        Physical; mental
    Special risks in particular occupations
    Preventive and counterbalancing safeguards

QUESTIONS

1. What industries or businesses in your community give rise to much smoke? dust? disagreeable odors? fumes?

2. What regulations protect the public from these nuisances and dangers? What regulations protect the workers?

3. What occupations require night work? Why?

4. What regulations are there regarding hours of work?

5. What are the advantages of standardized work hours? What are the disadvantages?

6. What is there to show that increasing the hours of work is undesirable? that reducing hours is undesirable?

7. What is the extent of unemployment in your community? What is the extent of irregularity of employment? What are the causes? What are the results? How can work be made more regular?

8. What can be done to reduce accidents on highways? on playgrounds? in theaters? in workshops?

9. What classes of the population receive special protection from the law? Why? Is the discrimination fair?

10. What are some undesirable effects of excessive division of labor? How can these undesirable effects be eliminated or counterbalanced?

11. What are some of the desirable effects of excessive division of labor? Who gets the benefits?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism, chap. v, Work and Fatigue.

Public Health Bulletin 106 (Studies in Industrial Physiology), Fatigue in Relation to Working Capacity.

Public Health Bulletin 78, Influence of Occupation on Health during Adolescence.

Public Health Reprint 448, The Bearings of Physiological Science on Industrial Efficiency.

Public Health Reprint 513, The New Science of Industrial Physiology.

Public Health Reprint 234, Physical Examination of the Worker.

Public Health Reprint 302, Plan for Education in the Avoidance of Occupational Diseases and Injuries.

Public Health Reprint 341, Relation of Economic Status to Health of Garment Workers.

Public Health Reprint 530, Dust Hazards in the Abrasive Industries.

Public Health Reprint 441, Heat Hazard in Industries.

Public Health Reprint 499, Code of Lighting for Factories, Mills, etc.

CHAPTER XXXVII

ORGANIZATION OF ACTIVITIES FOR PROTECTING HEALTH

Questions. **1.** What organizations influence my health? **2.** Why should we pay taxes for the support of hospitals? **3.** What is the advantage of going to a hospital when we are sick? What is the disadvantage? **4.** Why must druggists have state licenses? Why must nurses have state licenses? **5.** Why do doctors sometimes call in other doctors for consultation? **6.** Why cannot the doctor furnish the medicines needed instead of sending to the druggist? **7.** What are synthetic drugs? **8.** What is the need for laboratories in the health department?

294. Calling the doctor. Most people never think of consulting the doctor until they are already sick, just as some people do not lock the garage until after the car has been stolen. Modern science and modern organization teach us that *there are ways of preventing trouble* which in the long run are more economical and satisfactory than curing trouble after it comes.

The doctor examines the patient; he finds out what pains or discomforts he has; he looks at the skin, the throat, the tongue, the eyes; he counts the pulse and takes the temperature; he listens to the heart and to the lungs; he inquires as to stools and urine; he tries to get some information about the patient's diet, and about any recent strain, fatigue, chilling, or worry. Sometimes the appearance of the skin or of the throat suggests an infectious disease, and he takes a sample of the sputum or a swabbing from the throat for a bacteriological study; or he may take away a sample of the urine to be tested in the laboratory.

All these inquiries, including the laboratory examinations, are for the purpose of making a **diagnosis**, or a decision as to what ails the patient. This is not always an easy matter. A variety of causes may give rise to the same symptoms—indigestion or headache, fever or sore throat, a dry skin or a moist

skin. Each symptom may be present in many different combinations. Diagnosis is important because today we are no longer satisfied with "curing" each of the separate disturbances; we want to get at the main cause of the trouble and eliminate that.

295. Laboratories for diagnosis. If the doctor needs a special test or culture made, he may take the materials with him to his own laboratory. In larger towns and cities, however, he is more likely to send the samples to a commercial laboratory or to a board-of-health laboratory for more exact examination. It is really impossible for the individual physician to have the necessary equipment of microscopes and chemical apparatus and bacteriological apparatus to make a thorough examination of every kind of material that has to be considered in the diagnosis of disease. Moreover, it is impossible for each doctor to give the time from his attendance upon patients. In a well-organized laboratory one man specializes on certain kinds of microscopical examinations, another on certain chemical tests, another on certain bacterial cultures, and so on. This high degree of expertness is possible only where a laboratory serves a large number of physicians and their patients; and since many of these examinations, especially those that have to do with contagious diseases, are of concern to the whole community, many cities maintain such laboratories and so report promptly to the health officers the appearance of certain kinds of diseases.

Similar laboratories are maintained in connection with many hospitals, since here it is important that a prompt decision be made in cases that may call for surgical operations, the administration of antitoxin, or other radical treatment.

296. Treatment and attendance. After the doctor has decided what ought to be done with the patient, or to him, the nursing and other treatment are commonly left to mother or sister, not because she is trained for this task but because she stays at home and all the extra home duties are thrown upon her. Where treatment of a particularly difficult or skilled kind is required,

a nurse is recommended. The individual is often unable to get the specialized service that he needs except by coöperating with others. In most cases a sick person does not need the services of a nurse all the time; in a hospital one nurse can give attention in rotation to a number of patients.

The same applies to the ordinary upkeep of the sick organism —feeding, bathing, etc. The doctor may give very minute instructions as to what the patient may and may not eat, how much, and when. In most homes, if this diet differs much from what is customary, there would be great difficulty in supplying it. In a hospital, or in the hands of a well-trained nurse, the details are looked after almost automatically.

Surgical cases that require the use of anesthetics are as a rule better looked after in hospitals than in homes. There it is possible to be prepared for many possible emergencies which the home cannot meet. It is possible to have specialized attendance from both nurses and orderlies, and to have special types of beds and other appliances designed to secure the comfort and safety of the patient and to hasten his recovery.

297. Drugs and supplies. In modern times systematic attempts have been made to find out just exactly *how* the various drugs produce their effects in the body, and just exactly the right *quantities* to use under varying conditions. It is also important to know whether a given name always stands for the same drug and for the same strength.

For these reasons there has gradually grown up an elaborate system of standards of all sorts of drugs. Every ten years there is published a revised schedule of what amounts to *definitions* of the various terms used in prescribing medicines. The exact proportions of the significant ingredients under each title are passed upon by a committee of experts; and the trained and licensed druggist keeps himself informed or guides himself by the *Pharmacopœia.*

In the case of certain powerful drugs this regulation of the *quantitative* side is very important. A little too much morphin or arsenic in a dose may sometimes make the difference between

getting well and not getting well, or the difference between remaining alive and not. The supervision of these standards is a matter of organization or teamwork of medical men, scientific investigators, pharmacists, drug dealers, and manufacturers. Through a study of how protoplasm and the different substances and structures found in protoplasm react to certain types of chemicals it has become possible to build up new kinds of compounds for the purpose of counteracting certain parasites or their toxins. These compounds are *synthetic*; that is, they are "put together" by the chemist out of simpler groups of atoms, and are unlike any substances found in nature. Some of them have brilliant colors, like the coal-tar dyes used for most of our textiles; others are white or colorless. Several have now been made that do actually cure certain diseases. The Germans have a preparation which destroys the parasite of African sleeping sickness. Acriflavin and gentian violet have been used successfully to overcome bacterial parasites in the blood of patients.

Other synthetic drugs produce *anesthesia*, or lack of sensibility. Chloroform and ether have been used for about a century, and, in certain minor operations, nitrous oxid, or laughing gas. These anesthetics put a person to sleep for a while. At present there are compounds that can be injected into the blood or into the spinal canal and bring about various degrees of insensitiveness. Local anesthesia is being used more and more, even for large operations. In this practice the patient does not lose consciousness, although he loses all sensibility in the parts treated.

In many cities the health department maintains laboratories for the production of vaccines and similar supplies. Some state laboratories inspect and supervise production by private commercial laboratories, and in every state there is some attempt to maintain standards of purity in these biological supplies. This service involves the raising and care of many animals (horses, rabbits, calves, guinea pigs, and rats), their close supervision and periodic examination, and skillful experimentation and testing, which are going on all the time.

298. Keeping well. Much of the trouble for which we call upon the doctor comes from the neglect of well-known principles of healthy living. There are defects of nutrition, neglect of exercise, overwork, exposure, getting run down, toothaches, and constipation—all matters that can be almost entirely and automatically avoided by correct living habits. Most of us, unfortunately, have not such habits, and small defects accumulate as time goes on. For these reasons we need a periodic inspection or examination to tell us where the weak spots are, or where deterioration has set in unawares. In schools the regular examination by the nurse or the visiting physician is a large factor in keeping the young people of a community well. These examinations show what the individual needs to look after, and may also help to check a possible epidemic before it gets well started.

The community activities that seek to make our environment safe—regulation of the air, water, food, and wastes—are often under different departments of administration; but they all have to do with keeping people in health. It is often necessary for two or more departments to coöperate, and at any time the health department may have to assume the direction of affairs in one of the other departments.

299. Preventing illness. The department of health in most cities and states is concerned chiefly with communicable diseases, no matter how they are communicated. For this reason it deals with problems of sanitation: the safety of waters; the removal of wastes; factory conditions; food inspection; inspection of hotels and restaurants; transportation; fly and mosquito extermination; the care of mothers and infants; the training of nurses, pharmacists, physicians, and dentists; laboratories of research and diagnosis; the distribution of vaccines and serums; the disposal of dead animals; and many other problems related to the prevention of disease.

The *location of the sources* of an epidemic takes special kinds of knowledge and skill that most physicians do not usually acquire; and after the sources are discovered, the activities for *preventing the spread of the epidemic* are of a different kind from

those followed by the medical practitioner. In both cases there is need for a fairly large organization of many kinds of workers.

The importance of preventing disease, as distinguished from keeping people in fit condition and from curing sick people, has been recognized in the organization of public-health service for the nation at large, and in recent years there has been increased coöperation among nations for the study of health problems and for the prevention of epidemics.

300. Research and education. As new problems are constantly arising, new investigations need constantly to be made, and those who have the special ability for this kind of work find opportunity to use their talents and to serve mankind. Much of the research bearing upon health and disease is carried on in the official laboratories of health departments of cities, states, and nations; a great deal is carried on in medical schools; but a great deal more is being done in special institutes, such as the Rockefeller Institute and other endowed laboratories, and in laboratories devoted to specialized problems in biology, chemistry, pharmacy, psychology, and other branches of science.

The results of these researches are as a rule very technical and of immediate use or interest only to specialists. They must be gradually combined with other knowledge and put into forms that the general public can use. The collection of this material for wider distribution depends upon such organized agencies for informing the public as newspapers, magazines, lecture bureaus, schools, broadcasting stations, and motion-picture producers, and such voluntary organizations as the tuberculosis societies, the Red Cross, the Public Health Association, the Mental Hygiene Association, the American Social Hygiene Association, the Child Health Association, and so on. Much valuable work along these lines is also being done by some of the larger life-insurance companies. Finally, we must not overlook the professional organizations, such as the academy of medicine and the dental society, which are constantly bringing to their members the results of experience and research, and so fitting them for better service in the interests of the public health.

ORGANIZATION OF ACTIVITIES FOR PROTECTING HEALTH

1. The needs of the patient
   - Examination and diagnosis
     - By the individual physician
     - By a consulting group
     - By a hospital staff

     With the aid of a special, private, hospital, or public laboratory
   - Care and treatment
     - By a member of the family
     - By a visiting nurse
     - By a private nurse
     - By a hospital nurse and staff
     - By a specialist
   - Drugs etc.
     - Prepared by a specialized laboratory
     - Standardized by professional committees
     - Supervised by official inspectors etc.
2. Keeping well (chiefly through sound personal habits)
   - Eating and drinking
   - Breathing
   - Exercise
   - Elimination and excretion
   - Cleanliness (including care of teeth)
   - Work and play; mental hygiene
   - Rest and sleep
   - Regard for special sense organs
   - Periodic examination
3. Research
   - On current problems in health laboratories
     - Public laboratories; hospitals
   - On technical problems
     - Hospital laboratories
     - Medical-school laboratories
     - University laboratories
       - Biological; chemical; pharmacological; psychological etc.
     - Research institutes
     - Government laboratories (city; state; national)
4. Education
   - Informing the public of important discoveries
   - Records and statistics
   - Academies and professional societies
   - Colleges and schools
   - Lectures; books; magazines; libraries
   - Newspapers; motion pictures; broadcasting
   - Insurance companies
   - Volunteer societies

QUESTIONS

1. What kinds of clinics are free to the public in your community?

2. How many free hospital beds are there in your community?

3. What is the Red Cross doing to promote public health?

4. What are the advantages of using the old-fashioned home remedies instead of modern drugs? What are the disadvantages?

5. How do synthetic drugs differ from patent medicines?

6. What departments of the city administration or of the state government carry on work related to health?

7. What supervision has the health department of your city or state over the water service?

8. Should school nurses be under the direction of the board of health or under the direction of the board of education? Why?

9. What changes in your conduct or habits have been produced by the services of school-health inspection? by anything you have been taught about health? by anything that was done by the physician?

10. Why is it necessary to have a federal health service in addition to what the different states are doing?

11. How do the newspapers in your community promote public health?

12. Compare papers and magazines that carry patent-medicine advertisements with some that do not. What other differences do you find?

REFERENCE READINGS

Hough and Sedgwick. The Human Mechanism. chap. xxxvi, Public Protection of Public Health; chap. xxxvii, International Health Relations.

Public Health Reprint 680, Relation of State Health Departments to Federal and Volunteer Health Agencies.

Public Health Bulletin 54, Organization, Powers, and Duties of Health Authorities: Analysis of Laws and Regulations.

Public Health Reprint 723, Some Child Hygiene Activities of the United States Public Health Service.

Public Health Reprint 850, The National Health Council as an Aid to Organized Health Agencies.

CHAPTER XXXVIII

THE DAY'S WORK IN RELATION TO HEALTH

Questions. **1.** How can the kind of work that you do benefit or injure your health? **2.** Can any person learn to do all kinds of work? Can every person learn to do all kinds of work? **3.** Why are there so many specialties in the medical profession? **4.** Can every kind of work be made interesting? **5.** Can every kind of work be made useful?

301. Healthful work. Since most adults spend the greater part of their waking hours at their special occupations, it is important that, so far as possible, they do work that is in harmony with their abilities, their tastes, and their interests. It is only in this way that we can get enough satisfaction from our daily activities to maintain our mental health and our productive efficiency. We cannot be happy unless we can achieve that personal success which comes from having something to show for our effort, or from doing things that we feel are worth doing. Even where they are able to earn enough money, many people are unhappy because they are not interested in the activities which their daily work requires, or in the results which their efforts produce. Much of the dissatisfaction, then, arises from monotony in the work, from the lack of meaning in the work, from the lack of interest in the outcome. For all these reasons it is very important for all of us to find out what kinds of work there are, what they require of the worker, what they offer to the worker, how we may fit ourselves for one line of work or another, and how we may fit into various kinds of work.

302. Skilled work and unskilled work. Every one of us wants to do the highest grade of work of which he is capable; every one of us wants to do work that is both satisfying to the worker and useful to the community; yet it is often difficult to tell in advance what the value of any particular work is going to be.

For example, we know that the doctor, the nurse, the dentist, the druggist, represent skilled occupations that have to do with making people well or with keeping them well; but we do not often look upon the unskilled trench-digger or truck-driver as engaged in health service. Yet, on account of the great division of labor in modern society, every bit of useful work may have some bearing on the health and well-being not only of the worker himself but of many people with whom he never comes in direct contact. The work of the untrained laborer, if directed to useful purposes, may be just as vital as that of the most skilled scientist or professional worker. In short, *all useful work* contributes to the welfare and health of the whole community.

303. Subdivision of service. You have long ago learned that it is possible for the physician to give so much of his time to his patients only because he can leave to others most of the work necessary to maintain his home and supply his personal needs. The house in which he lives was designed and built by others; the furniture and furnishings come from many factories and shops; the fabrics of which his clothes are made and their tailoring depend upon people that he has probably never seen; the house-cleaning, the preparation of his meals, and the thousand other details are looked after by people of all degrees of skill and training. If he had to do all these things himself, he could not give his best thought and efforts to the welfare of his patients. The same sort of thing is true in the home of the minister and the machinist, of the printer and the plasterer. This is only another way of saying that *there is division of labor* and a corresponding *exchange of services*, a corresponding *interdependence* of all members of the community. It does not show how the various occupations are particularly related to health.

304. Specialties directly related to health. The profession of medicine is itself subdivided into a large number of specialties; in fact, the general practitioner is getting to be very scarce except in smaller towns. One division of specialists is based on the more intensive study of particular organs or systems of organs; so we have dentists, oculists, throat specialists, stomach

specialists, ear specialists, heart specialists, nerve specialists, and so on. Another division is based on the study of particular kinds of diseases, or particular periods, or particular conditions that can be studied more intensively; thus, there are specialists in tuberculosis, in cancer, in diabetes, in children's conditions, in childbirth, in nutrition, in the conditions of old age, in industrial hygiene, in school hygiene, in tropical conditions, in epidemics, in mental hygiene, in mosquito extermination, in health education, in diagnosis. These men and women are all doctors, but they gradually drift apart so that the work which one specialist does in the course of a year is entirely unlike that done by another. One of them may spend day after day in interviewing patients; another, in performing surgical operations; another, in giving instructions to nurses; and many of them never see a patient for years at a time.

Various classes of helpers furnish the supports for the doctors' daily work. We know, of course, of the nurse, of the anesthetist (who administers the anesthetic for the surgeon), and of the various hospital attendants and other assistants; but there are many helpers who never come near the patient. Laboratory workers are concerned with the detailed examination of materials for diagnosis (see page 399)—chemists, microscopists, bacteriologists, physiologists. Then there are those engaged in various occupations that directly aid the technicians. Specimens have to be prepared; apparatus has to be prepared and kept in condition; various chemicals and culture media (in which bacteria are grown) have to be prepared, often with extreme pains and accuracy; animals have to be fed and kept in good condition; records, reports, and calculations have to be made. There is need for many kinds of workers that we do not commonly regard as related to health promotion. A trained clerical worker, for example, might get a job in a broker's office or in a hospital office, in a cigar-factory office or in a board-of-health laboratory. In any case she might have to make records, conduct correspondence, or apply her arithmetic; in some cases she would be a health worker, but not in others.

The dentist has to rely upon someone with a keen color sense to match artificial teeth, upon various supplies whose value depends upon the skill and accuracy of chemists, and upon very accurate workmanship on the part of his helpers. The oculist must rely upon skilled workers in glass and metal, and upon physicists. The orthopedist must rely upon skilled workers in leather, wood, metal, cloth, and rubber. The various specialties have to be reënforced by many kinds of mechanical, chemical, biological, or other technical skill.

Since the supply of drugs comes chiefly from large factories, workers of all degrees of skill are employed in its production—foresters, electricians, engineers, shovel men, physiologists, package-wrappers. There is very little difference between the character of work done by advertisers, designers, and salesmen who handle specialties needed by physicians and dentists, and that done by workers who handle merchandise for the general public.

305. Specialties indirectly related to health. The administration of many municipal and state agencies requires the coöperation of technical experts, some of them specialists in health problems. A city's water supply, for example, needs constant inspection. Supervising markets and milk supplies includes examining cattle and dairies and stables, sampling and testing milk and other foods, inspecting bottling stations and containers, by specialists who understand the relation of various conditions to health. Most of the work in these departments is done by men and women who cannot ordinarily be considered health workers in any sense. Yet their work, which is quite as necessary as that of the specialists, must be valued in relation to the main purpose, that is, health. A negligent watchman who is set to patrol the watershed, a negligent bottle-washer in a dairy or in a vaccine laboratory, a negligent clerk in a board-of-health office may, through a comparatively slight error or oversight, give rise to very serious disturbances in people's health. If these do their work well, the rest of us are so much the more secure.

Less frequently do we consider as health workers the many people who supply us with our food, our clothing, our fuel, our housing; yet every one of these, from the plowman and shepherd and lumberman and miner to the cook and clothing designer and architect, can do something that either helps or hinders the health of the community. It is necessary to produce an abundance of food, to preserve it, and to prepare and serve it most effectively; it is necessary to build houses that can be properly ventilated and heated or cooled; it is necessary to make suitable clothes; and so on. These things are so essential to health and well-being that we take them for granted. By the division of labor everyone who is of any service at all may be of service to health. We must work; our work should therefore be as helpful as possible in promoting the health of the worker and the welfare of all.

THE DAY'S WORK IN RELATION TO HEALTH

1. Work and health
    - Relation of the work to the worker's health
        - (Working conditions)
        - Abilities
            - Strength; talents
        - Interests
            - In people; in things; in ideas
        - Opportunities
            - For self-expression
            - For seeing the results of effort
            - For growth
            - For seeing the value of product
    - Relation of the work to the welfare of others
        - Products or results
            - Useful; injurious
2. Division of labor
    - Specialization; exchange of services; interdependence
3. Physicians and medical specialties
    - Specialists on organs

Dentists	Throat specialists	Heart specialists
Oculists	Stomach specialists	Nerve specialists

- Diseases especially studied
  - Tuberculosis
  - Cancer
  - Diabetes
  - Hookworm disease
  - Rheumatism
  - Mental disease
- Specialized methods
  - Surgery
  - Diagnosis
  - Serum therapy
  - Epidemiology
  - Study of nutrition
  - Psychoanalysis
- Other specialists
  - Hospital superintendents
  - Sanitarians
  - Obstetricians
  - Research workers
  - Pediatrists
  - Industrial hygienists
  - School physicians
  - Orthopedists

4. Those occupied in direct support of medical work
   Nurses; anesthetists; hospital attendants and assistants
   Diagnosticians; microscopists; biologists; bacteriologists
   Pharmacists; instrument-makers; various mechanics
   Clerical workers; statisticians; preparators
5. Those engaged in occupations indirectly related to health
   Inspectors; samplers; testers; food-preservers; cooks
   Investigators; research workers
   Plumbers; street-cleaners; ventilating and heating engineers
   Food-producers; house-builders; clothing-makers; fun-makers; musicians

QUESTIONS

1. What kinds of medical specialists are there in your town?

2. What kinds of dental specialists are there in your town?

3. What is the difference between an oculist and an optician?

4. What other occupations in your town are directly related to health promotion or health protection?

5. How can you tell whether to go to a specialist or to a general physician when you are sick?

6. What is the advantage of going to a specialist? What is the disadvantage?

7. What is the advantage of being a specialist? What is the disadvantage?

8. What industries in your town are unfavorable to the health of the workers? to the health of the public?

9. What occupations and industries in your town are essential to health? What ones promote health without being essential?

10. Of the occupations that you know about, which are likely to disagree with your health? Why? Which are likely to agree with your health? Why?

11. In what occupations are you interested? Which of these are related in some way to the health or welfare of others? Which are in no way related to the health and welfare of others?

12. Under what conditions would it be advisable for a person to change his occupation?

13. Under what conditions could large numbers of unskilled workers be used to promote public health?

14. How can a librarian promote public health? a farmer? a stenographer? an artist?

15. How can low-grade work be made healthful? interesting?

16. How are laundries in your town supervised? stables? bakeries?

REFERENCE READINGS

Gowin, Wheatley, and Brewer. Occupations (revised edition). Selected chapters in Part II.

Public Health Reprint 638, Modern Medicine and the Public Health.

Census of Manufactures, 1921. Drug Industries, Druggists' Preparations, Patent Medicines, etc.

Public Health Reprint 189, Pure Drugs and Public Health.

Public Health Reprint 254, Purity and Strength of Household Remedies, and Possible Sources of Danger.

Public Health Reprint 783, The School Nurse, her Duties and Responsibilities.

Children's Bureau. Publication 47, The Public Health Nurse and how she helps to keep Babies Well.

PART III. THE BIOLOGY OF WEALTH

WEALTH

Under simple conditions of human living very few material things are accumulated. It takes about all the time there is to get the bare necessities and to fight enemies of one kind or another. The only surplus is likely to consist of weapons, simple tools, and trophies of the chase or of war.

With increasing division of labor, and with the growth of agriculture, industry, and commerce, production goes on at an increasing rate. It becomes possible to construct more permanent buildings and bridges, ships and docks, roads and railways, and to store up large accumulations of food, clothing, fuel, tools, raw materials, ornaments, and so on. All these usable objects and materials constitute a people's wealth—the material basis for their welfare.

In considering the wealth of a people we sometimes include all the natural resources, such as fertile soils, minerals, mines, forests, water power, wild life of land or water, and so on. All these things can be converted into usable wealth by means of the skill and science available among the people. We shall give our attention to those elements of wealth that are derived from an understanding of life or of living things.

PRODUCTION

CHAPTER XXXIX

PLANTS AND ANIMALS AS SOURCES OF USEFUL MATERIALS

Questions. **1.** Why are there injurious insects? **2.** Why are there poisonous plants? **3.** Are all things that exist of use to man? **4.** How can we tell what use may be made of a plant or an animal? **5.** Why do people have gardens? **6.** Why do people keep goldfish or other pets? **7.** What are the most useful plants and animals?

306. Good and bad organisms. What is the use of thistles? Why are there bedbugs? Is the milkweed a good plant or a bad plant? What is the good of jellyfish? These questions represent something more than a healthy curiosity about the things discovered. They mean that in the mind of the questioner everything in the world is in some way related to human welfare. They mean especially, in many cases, that everything must exist only or chiefly to serve mankind. This point of view is well expressed in a little story told by Thomas Henry Huxley (1825–1895), a great English biologist, but not in exactly these words:

There was once a black beetle living in a loaf of bread, and she lectured her offspring in some such way as this: This is a wonderful world, my dear children, and you should be very grateful for all that has been done for you by our great ancestor, Big Beetle. He made the sun to shine and the rain to fall, so that plants might grow. He made farmers to plow the soil and sow the seed for us, and to harvest the grain. He made truckmen and others to carry and store the grain for us. He made millers and engineers to build mills, so that the grain might be ground into nice white flour. And he made bakers and coal mines and miners so that the flour could be made into bread, so that you and I, my dear children, might have a comfortable home and plenty of food.

We know, of course, that the farmer and the miller and the baker do not exist primarily for the benefit of the beetle and her family; but we can understand why, from the narrow outlook of the beetle, it looks for all the world as though the whole universe were planned to revolve around her family and to serve it. We must simply be on our guard against drawing our own conclusions from the depths of our ignorance, as did the beetle.

Man is one of many thousands of species of animals living upon the earth. Man and these other animals can live here only because many species of plants are *capable of producing food* out of the inorganic materials in air, soil, and water. Some of the animals and some of the plants are helpful or useful to man in various ways. Some species are injurious to man, directly (as certain parasites on his body) or indirectly (as parasites upon organisms that he wishes to keep alive). As for the rest, all we can say is that we have not yet found out how we can use them or how they can affect our welfare; but we certainly cannot say that any of the numerous plants and animals *exist because we need them* or because there is some need of our being injured by them.

307. Utilities. The division of labor in carrying on the work of the world has gone so far, and industry has developed so much, that many kinds of materials are important for many different uses that cannot be classified under food, clothing, and shelter. Paper, for example, has come to be a necessity in every branch of industry, business, government, or study. It is used not only for books and magazines and newspapers but for correspondence and records and accounting; for papering our rooms, waterproofing our roofs, and wrapping our groceries and clothing; for making money and washtubs and car wheels. A classification of the main directions in which materials are put to use would make a very long and awkward catalogue, but the main kinds of materials that are derived from plants and animals may be grouped somewhat according to the way in which we make use of them.

308. Food. For people the world over, food is the largest single item in the cost of living. We have already seen (page 107) that all of our food comes either directly from the bodies of chlorophyl-bearing plants or indirectly, by way of animals that feed upon green plants. A very small portion of the total food supply of human beings comes from fungi (mushrooms), which in turn get their nourishment from the remains of other living things. We also make use of organisms in the preparation of food. For example, the yeast[1] used in baking, and the molds used in curing cheese, are not themselves parts of the food we eat, but they are essential agents in making food. The nitrogen-fixing bacteria (see page 300) also add indirectly to our food supplies, since they enable the plants of the bean family to utilize nitrogen from the atmosphere, and since they help to keep the soil usable for other food crops.

309. Fibers and hairs. The bulk of our clothing material is woven from various plant and animal fibers, although such fibers are used for other purposes than the making of clothing—for cordage, burlap, sailcloth, aëroplane wings, bunting, and so on. Cotton, flax, and hemp are the most important fiber plants. In the manufacture of cotton we use the fine fibers surrounding the seeds after the fruit is ripe; in making linen and hemp we use the bast fibers from the stem.

Wool is the most valuable of animal fibers. Besides the wool of the sheep, goat's hair and camel's hair are also used to a considerable extent. Silk is made from the fine thread spun by the larva of the silk moth as it passes into the pupa stage. Attempts have been made to utilize the corresponding silk of certain large American moths, but so far without success; and up to the present time experiments with the cocoon silk of various spiders have also failed to establish workable methods.

[1] In recent times compressed yeast (a mixture of yeast plants with starch grains) has been offered to the public as food for supplying vitamins. While it is true that yeast does contain vitamin B, we can more conveniently and more economically get what we need of this substance in connection with a normal mixed diet (see pages 147, 105).

Fabrics made from the hairs of other animals are not of great importance, but the furs of many mammals are important not only commercially but because they supply warm garments for millions of people who are exposed to cold weather. Bristles and other hairs are of value in the making of brushes of all kinds. The hides of animals supply the staple leather for most of our shoes and for belting, luggage, gloves, and so on. Most of our leather comes from the skins of mammals, but alligators and other reptiles have furnished valuable leathers, and the skins of various sharks have been used.

Related to the hairs of mammals are the feathers of birds, which have their chief practical use in the stuffing of pillows and as ornaments. Quills formerly served as writing pens, but they have been almost entirely replaced by metal pens.

Most of us recognize fibers in the many different forms in which they are used, but most of us do not know that *paper* and the transparent *film* used in motion pictures are derived from plant fibers. Some of the finest paper is made of linen fibers in old linen rags; but most of the paper, of which millions of tons are consumed every year, is made of the cheaper fibers of *wood*. Hundreds of acres of forests are consumed every week to supply stock for the daily newspapers alone. Celluloid for photographic films and other articles is made of the best quality of cotton. Methods are being developed for utilizing cheaper fibers, such as wood, for some grades of celluloid or substitutes.

In different parts of the world the straw fibers of many plants have been used to some extent for clothing, but chiefly for rugs, mats, screens, furniture covers, and similar articles. The coconut fiber, called *coir*, which we see chiefly in the form of doormats, comes from the husk covering the fruit of the coconut (see Fig. 179). It is used extensively for cordage where the coco palm is common.

310. Shelter. From clothing to shelter is a logical step, since clothing is the kind of shelter that we carry around with us, whereas a house is the kind of shelter that usually remains in a fixed place. Since the purpose of the two is very much the same,

it is not astonishing that the same materials should be to some extent usable for both. Timber is perhaps the most widely used building material; its use ranges from the log cabin of the pioneer to the highly finished woodwork of modern city dwellings. Where there are no large trees other plant material may be available, as the bamboos used in parts of China, Japan, and India. The thatch of roofs still used in many parts of Europe and Asia is supplied chiefly by the stalks or straw of plants of the grass family or by leaves and husks. In buildings constructed of stone and steel, or of other mineral matter such as brick and concrete, organic matter is of value to prevent too rapid changes in temperature. For this purpose wooden finish is used on the inside, or various composition boards in which wood fiber forms an important part. In the same way prepared papers are often used in the walls, under the floors, and under the roofs of houses. Animal materials are very seldom used in building houses, but to some extent cow hair is still used as a binder in the making of mortar.

Occasionally *peat* has been used as a building material. Peat is a mass of earth in which there is a large proportion of decaying vegetable matter; it can therefore also be used as fuel. It is found in bogs, and at certain seasons of the year it may be cut out in rectangular blocks and allowed to dry in the sun. It is believed that peat represents the early stages in the process of coal formation.

The problem of shelter includes, of course, that of maintaining protection from the cold; and that suggests fuel. Most of the fuel that we use is obtained directly from wood; nearly all the rest indirectly, for when we burn coal we are using the carbon deposited millions of years ago in trees long dead, and when we burn oil or gasoline or kerosenes we are using the products of chemical change in plants of past ages. Alcohol as a fuel can be produced also from wood and other vegetable matter, although the tendency is to get more and more of it from the waste products of industries in which vegetable material is used —molasses from sugar refineries, for example.

Animal sources of fuel are less common today than they were formerly, when whale oil was burned to some extent under special conditions, both for heat and for light.

311. Contributions to health. Plants and animals furnish many substances of direct and indirect value in maintaining our health and efficiency. On the side of keeping clean we have, first of all, *soap*, which is made by treating plant or animal fats with alkali solutions. Brushes, sponges, wash cloths, and similar aids to cleanliness all represent the use of plant and animal material as contributions to health.

The greater part of our drugs consist of plant products. The exceptions are (1) a very few mineral products that are used in the pharmacopœia (see page 400), such as acids and alkalis and a number of salts, and (2) the *synthetic* and coal-tar products developed by modern chemistry. A very few are derived from animals. Gummy or jellylike substances are obtained from seaweeds (algæ) and lichens, as well as from seed-bearing plants. Among the latter, gums are obtained from seeds, stems, and roots. Camphors and resins, as well as a great variety of oils and essences, all derived from plants, are used as flavoring agents, as irritants, and as antiseptics. Compounds related to tannin are obtained from rhubarb, witch hazel, and other plants for their astringent, or puckering, properties. The drug ergot is obtained from rye that has been attacked by a parasitic fungus.

The most powerful drugs, the *alkaloids*, are obtained from plants; and until recently, when synthetic chemistry attacked this problem, we had no substitutes for them. These organic substances, which are "like alkalis" in that they can combine with acids, are all more or less violent poisons. Each produces some distinct effect upon protoplasm, so that they have been very useful in dealing with special types of situations. For example, *morphin*, derived from the juice of the poppy fruit, dulls the senses or actually puts one to sleep, while leaving the imagination unrestrained by actual facts or consistent thinking. *Cocain*, obtained from the leaves of the South American coca plant,[1] produces insensi-

[1] This is not to be confused with the coco palm, from which we get the coconut, or with the cacao plant, from which we get chocolate and cocoa.

bility to pain in the regions of the body into which it is injected. *Quinine*, obtained from the bark of the cinchona, or calisaya, tree of the madder family, another South American plant, is poisonous to the malaria plasmodium in quantities that are harmless to most human beings. *Atropin* is obtained from the roots and leaves of the belladonna plant, of the potato family; it paralyzes involuntary muscles, and for this reason is often applied to the eyes so as to permit an examination uninfluenced by the reflexes that would occur with change in illumination etc.

Musk, obtained from the scent glands of the musk deer, and ambergris, derived from the bile of the whale, have been used as bases for producing perfumes. Spermaceti is also obtained from the whale. Ammonia was formerly obtained largely from horn cuttings and shavings (hence the old name *hartshorn*), and from the dung of camels and other animals. Cantharides, a local irritant, is obtained from a beetle. Ox gall is used to correct certain conditions in the intestines. Extracts from the thyroid gland of sheep and other gland extracts are used to remedy various defects in the working of the human organism.

Many materials used in connection with the care of the body in health as well as in disease, but not in any sense drugs, are derived in large measure from plants and animals; rubber, chamois skin, glue, and alcohol are examples.

312. Materials used as means. Wood, which has so great a variety of direct uses, is also the most common material for the making of many kinds of instruments or tools. It is a large factor in many kinds of vehicles and transportation systems, including boats and railroad ties, and in containers for storage and shipping. Cork and rubber have numberless uses in tools, instruments, devices, and apparatus, including means of transportation. Glue, rosin, turpentine, linseed oil, tanning materials (obtained chiefly from the bark of various trees), leathers, and fibers are some of the materials that we use in carrying on the world's work. We use these materials not by consuming them directly as food, or in immediate protection or other service to the body, but as tools, machines, and other devices that enable us to get things that we need.

313. Materials for esthetic uses. Clothing is used partly for ornament. Indeed, primitive peoples living in the tropics, where they need no protection, adorn themselves with all sorts of trinkets and decorate their bodies with paint. These things do not agree with our own tastes; yet much of our interest in clothing is of exactly the same kind, and within certain limits it is quite as proper for us to get pleasure out of this kind of beauty as to get it from the natural beauty of the earth and the changing sky, or from plant and animal forms; and it is quite as proper to apply our skill in increasing our own beauty and that of our clothing and furniture as it is to paint a picture or decorate china. So we get buttons and brooches and combs from the shells of mollusks and reptiles (tortoise) and from the bones and horns of mammals; we make bright dyes from insects (cochineal) as well as from many plants; and we use the plumage of birds and the cocoons of the silkworm.

The materials out of which we make our musical instruments are chiefly woods of many kinds, and catgut (which is usually calf gut) and horsehair, used in making violin bows. Many of the devices that we use in playing athletic and other games are made of plant and animal material.

Closely related to the esthetic is our use of materials solely for their taste or flavor. Thus, seasonings and spices are of no value as food, yet they are satisfying and so worth having. There is, of course, some danger in their excessive use, since we may come to depend upon them to make our food palatable. In the same class we would place various fruit flavors with which we make the drinking of water more interesting, tea and coffee, and perhaps also tobacco in various forms.

314. Tobacco and smoking. The tobacco of commerce is made of the leaf and stalks of *Nicotiana tabacum*, a member of the potato family. This family includes the very useful tomato plant, the eggplant, the belladonna, and the nightshade. Some of these plants produce more or less violent poisons. Even the tubers of the potato, while they are still green, contain a poisonous alkaloid. The alkaloid in the tobacco, *nicotin*, is also poisonous, whether taken into the stomach or injected into the

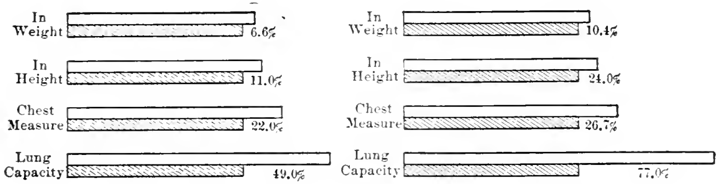


Fig. 173. Relation of smoking to physical growth

The first column shows the average advantage of non-smokers (indicated by white space) over occasional smokers (indicated by shaded space). The second column shows the average advantage of non-smokers over regular smokers. It is not at all likely that the smaller, lighter, weaker boys were the ones to take up smoking in larger proportions. The differences shown by these records must be, at least in large part, due to smoking. These measurements are from the physical-training department of Yale University

blood. Whether tobacco is injurious as ordinarily used cannot be known for all people, since there is a great deal of variation as to how we react to it. Apparently adults can stand more of it than young people; some can stand a great deal; some none at all. Most of us could probably get used to it if we made the effort. It is questionable, however, whether those who are in the habit of using tobacco are helped as much as they think or injured as much as its opponents think. Harmless enjoyment

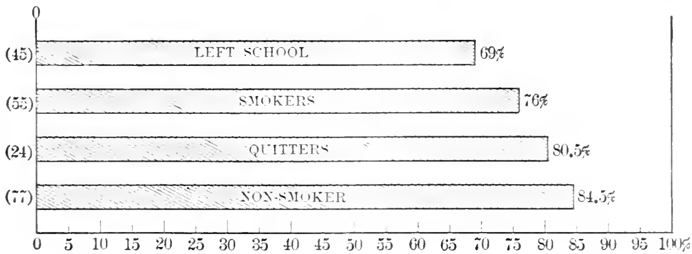


Fig. 174. Smoking and school standing

The school grades of four groups of Illinois high-school boys (two hundred and one in all). The numbers in parentheses give the number of boys in the group. The forty-five who left school during the year were habitual smokers. Twenty-four of the boys had learned to smoke but had given up the practice. The average grade of the ten highest smokers was 78.9 per cent. The average of the ten highest in the school was 90.9 per cent; none of these smoked. We cannot assume that the grade differences between smokers and non-smokers are due entirely to the fact of smoking. It is likely that the more scholarly boys do not take to smoking as much as the others. If none of the boys smoked, some of those with poor scholarship would nevertheless still be in the low-scholarship groups

ought to be tolerated, but it is just as well for us to know what it is that yields the enjoyment. Generally speaking, then, it is not the effect of the nicotin. Very often, especially with young people, it is the feeling that they are doing something wonderful—like grown folks! In many cases it is the sight of the curling smoke; this has its fascination no matter what the source of the smoke may be, and many experienced smokers assert that they cannot enjoy a smoke in the dark. In many cases the satisfaction really comes from the handling of the cigar or pipe, working it about with the muscles of the lips and tongue, and so on; many a smoker has enjoyed his smoke very much until he suddenly discovered that he had forgotten to light the tobacco. Here the tobacco might just as well have been replaced with a stick of chewing gum or the baby's pacifier.

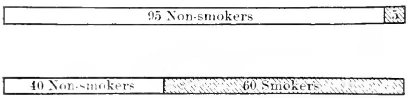


Fig. 175. Smoking and scholarship

Showing the proportion of smokers (shaded space) and of non-smokers (white space) among the students of highest rank (first bar) and among students of ordinary rank (second bar) at Yale University. In several colleges records show that in any given graduating class the smokers are on the average older than the non-smokers. This may show the extent to which smoking—perhaps in association with other unhygienic habits—retards a young person in his progress

On the other hand, it must be said that, for those who do not smoke, the odor of the smoke and the spoiling of the air are real impositions. As David Starr Jordan said, "We ask a free passage through the world, *with pure air all the way*." Of all the fires in this country, more are caused by the careless smoker than by any other one thing. As for the smoker himself, there is evidence of (1) interference with digestion, (2) chronic irritation of the linings of the air passages and lungs, (3) disturbed heart action, (4) bad effects upon the nerves, (5) stunted growth (Fig. 173), and (6) disturbances of the eyes. These effects of smoking need not all appear in any one person; and it is quite possible that they are not always due to the nicotin, of which only a very small portion, at the worst, enters the system. Poor scholarship among high-school students (Fig. 174) and college students (Fig. 175) may involve other factors besides smoking.

In many parts of the world the natives make use of various materials containing some alkaloid to help them forget their troubles or, as they suppose, to increase their joys. In many cases these substances tend to break down the control which

the individual has over himself and over his environment. It should be the ideal of all thinking persons to make themselves so far as possible independent of these various devices that interfere with or modify the action of the nervous system. In the case of extremely harmful drugs, such as opium and cocain, it is necessary to make strict regulations to prevent people from becoming dependent upon them. Most of us should be able to manage such things without the policeman or other state officer, and to find forms of enjoyment that are fully satisfying but without any danger to our health and our responsibility.

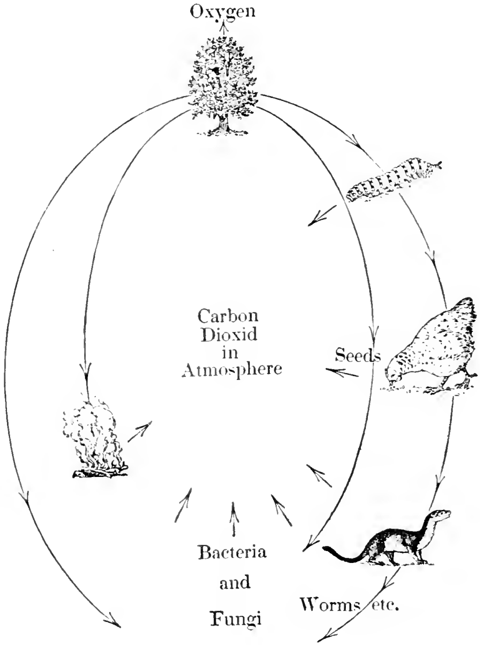


Fig. 176. The carbon cycle

Fires and all kinds of living things are constantly throwing carbon dioxid into the air. Green plants, represented by the tree in the diagram, withdraw carbon dioxid from the atmosphere and return oxygen. The material of the green plant is made up in part of the carbon derived from the carbon dioxid. This material serves as food for animals and as fuel for fires. The animals oxidize this material, or *they* are eaten by other animals. Finally, the carbon of larger plants and animals is oxidized by simple organisms, such as bacteria and fungi, and is returned to the atmosphere. Nitrogen, oxygen, and other elements circulate about in a similar way

315. Indirect uses and services. Plants and animals may serve us without our making direct use of the materials in their bodies. The by-product of photosynthesis, oxygen, comes to us through the air as part of the continuous exchange

of materials in the vast cycles of life. In common with other animals and with plants we discharge carbon dioxid and nitrogenous wastes. Some of these are used by green plants directly; others find their way into the green-plant organisms only after having gone through the protoplasm of various bacteria, protozoa, and larger animals. After a long chain of chemical changes some of the elements come back to us in new combinations (see Fig. 176).

Many plants and animals serve us as a means of keeping alive the organisms in which we have a direct interest; bacteria make it possible for soil to increase our crops, and field crops are used as fodder to increase our supplies of useful animals. Moreover, the forest and the forest floor, very complex groups of many organisms, are of vital importance to us in keeping us continuously supplied with water (see section 394), although many of us never see these organisms.

Less directly, but still vitally, we depend upon many insects for the distribution of pollen for important wild plants as well as for many cultivated plants; and we depend upon insects and birds and other animals to keep in check various enemies of the forest, of the crop plants, and of other useful organisms.

Finally, we make direct use of many animals for immediate service, especially in transportation. Besides the horse, man has depended upon the camel, the ox, the elephant, the reindeer, the goat, and the dog to help carry his burdens and transport his wares. From many animals we also get direct service in the form of companionship and amusement.

Thus we may see that living things outside our own species are important to us, not only because we could not maintain physical life without them but also because they have played a large part in making possible man's civilization and his spiritual development and satisfaction.

PLANTS AND ANIMALS AS SOURCES OF USEFUL MATERIALS

1. Man's place in the world
    - The center of the universe
        - In his own opinion; compare bread beetle or clothes moth
    - One of many species
        - Some useful; some injurious
        - Greatest utilization depends on better knowledge
        - Greatest amount of protection depends on better knowledge
2. Material utilities furthered by plants and animals
    - Maintaining life
        - Food
        - Shelter
            - Clothing
            - Housing
            - Fuel
    - Maintaining health
        - Cleanliness
        - Drugs
        - Accessories
    - Carrying on work
        - Instruments and tools for various purposes
            - Raising food and other materials
            - Working over (manufacturing)
            - Storing and preserving
            - Transporting
            - Recording
    - Enjoying life and leisure
        - Means of play and amusement
        - Satisfying the senses
            - Taste
            - Odor
            - Sound
            - Sight
            - Ornamentation and beautifying
                - Of the person
                - Of the surroundings
                    - Homes
                    - Other buildings
                    - Grounds
                    - Streets
                    - Parks
    - Various direct and indirect services
        - Transportation
        - Pollenation
        - Keeping living enemies in check
        - Control of water supply (forest and humus)
        - Maintaining of fertility of soil
        - Companionship and amusement

QUESTIONS

1. What are the most common wild plants in your region? the most common cultivated plants? the most common wild animals? the most common cultivated animals?

2. What are the most useful plants in your region? Why?

3. What are the most useful animals in your region? Why?

4. What plant materials are used in great quantities in the principal industries and occupations of your community? How are they used?

5. What animal materials are used in great quantities in the industries and occupations of your community? How are they used?

6. What different kinds of plants are represented by your clothes, your books, and the contents of your pockets? What animals?

7. What plants are represented in your house and its furnishings? What animals?

8. What plants are represented by the equipment and apparatus used in your school? What animals?

9. What plants are represented by the materials and apparatus that you use in your games and athletics? What animals?

10. How are plants used in your community to make a more attractive place in which to live? How are animals used?

11. How can the abundance of a particular species of plant or animal (reindeer; oranges; whales; cotton; sugar cane; sheep; cattle) influence the whole mode of life of a community?

REFERENCE READINGS

Sargent, F. L. Plants and their Uses, various chapters.

Reese, Albert M. Outlines of Economic Zoölogy, various chapters.

Daugherty, L. S. and M. C. Principles of Economic Zoölogy, various chapters.

Price List 38. Animal Industry, Farm Animals, Poultry, and Dairying (from the Superintendent of Documents, Government Printing Office).

Price List 44. Plants, Culture of Vegetables, etc. (from the Superintendent of Documents, Government Printing Office).

CHAPTER XL

CLASSES OF PLANTS AND THEIR ECONOMIC IMPORTANCE

Questions. 1. What is a weed? Why are there weeds? **2.** Is every plant that grows either useful or harmful to man? **3.** What is the most useful family of plants? **4.** Do all the useful plants belong to the same family? **5.** Are there any families of plants that are altogether good or altogether bad for man? **6.** Are there any plants of which we can use all parts? **7.** Do all trees belong to the same family? **8.** What makes some woods more valuable than others?

316. Meaning of economic relations. The word *economic* comes from a Greek word meaning "house," and formerly pertained to the *management* side of housekeeping. It has gradually come to mean "pertaining to wealth and welfare" in so far as well-being depends upon material things. In this sense we speak nowadays of the economic importance of anything when we have in mind its contribution to or interference with human welfare. All the utilities that we can find in a plant, as well as all the injuries that it may cause, either directly or indirectly, make up its economic relations. Most important groups of plants and animals have members that are of some use to us, as well as members that are in some way harmful. Indeed, a single species may be both a source of satisfaction and a source of trouble. The dog, for example, has long been man's friend and is of value in many ways; but he is also a potential means of bringing the dreadful disease rabies, and more than once a dog, like Carlyle's "Diamond," has been the cause of serious loss to his master.

A large part of man's practical activity is organized on a commercial basis—that is, on the basis of buying and selling, or exchanging goods and services, with money passing between buyer and seller. Still, there are many values in life which

cannot be measured in money. We may consider the good or the harm that the different kinds of organisms[1] do to us, even if we cannot measure it, just as we accept the oxygen of the air, water, and sunshine without any business transactions; these are without price but indispensable.

317. Schizomycetes. The fact that bacteria cause the decay or decomposition of organic matter can be used directly in the preparation of sponges for commerce. The sponges are allowed to lie in tanks of water until the dead cells are completely destroyed by bacteria, leaving only the familiar horny skeletons. These are washed clean and dried for market. A similar process, employing different species of bacteria, brings about the *retting* (really, "rotting") of the soft portions of flax and hemp stalks, and so allows the bast fibers to become separated.

The action of bacteria is used in making vinegar out of cider, wine, or other liquids containing alcohol. The bacterial ferments cause a partial oxidation of the alcohol into the acid of vinegar. In making sauerkraut and other kinds of pickles, as well as in the curing of silage, bacterial fermentation is used. In the work of the dairy, from the souring of milk to the curing of cheese, bacteria are used at several points. Cheeses of the Cheddar type and various cream cheeses, as well as butter, depend for their flavor upon the particular species of bacteria present during the souring.

It is very likely that bacteria play a large part in the curing of tobacco and in the making of hay, although the problems connected with these processes have not been thoroughly worked out as yet. In the preparation of indigo dye from the extracts of certain plants of the bean family it is likely that an oxidizing ferment from certain bacteria performs an essential part of the work. In the preparation of hides for tanning, certain of the changes are brought about by bacterial fermentation.

[1] For the general plan of classification see Chapter VII. Many plants and animals are related to human welfare by the mere fact that they fit into the general life cycle whereby the material of the earth, water, and air is constantly circulating from one kind of protoplasm to another. Here the relationship is not always specific; that is, one kind of plant or animal could serve as well as several others (see Fig. 176).

In some cities the sewage is collected in large tanks, and the decaying mass of organic matter is converted into harmless or less offensive forms through the action of bacteria. After the fermentation the sludge, or solid deposit, may be used as fertilizer.

Pure cultures of harmless bacteria have also been used medicinally to replace those that are already present in the intestines, interfering with digestion or absorption or producing objectionable substances.

It is impossible to say that bacteria, on the whole, are more beneficial to man than harmful. This illustrates, then, a general fact about the groups of living things.

318. Algæ. For centuries a number of the larger seaweeds have been used in Japan as sources of food. *Agar-agar*, a substance like gelatin, obtained from some of these seaweeds, has been for many years imported into Europe and America for use in laboratories as a convenient medium in which to grow bacteria. Because it can absorb large quantities of water and swell up it has come to be increasingly used as a help in constipation. Other seaweeds, the kelps, are used as a source of iodin, and experiments with kelp are now being made in the hope of extracting potassium on a commercial scale. "Irish moss" yields a gelatinous material sometimes used in puddings.

The diatoms, which are the most common plants in the vast floating life of the ocean, are microscopic one-celled organisms with strange, sandy shells that are often beautifully marked. In ages past accumulations of such shells have built up vast deposits of *fuller's earth*, which is used in scouring soaps, for polishing wood, and for other purposes which require a very fine, hard powder.

319. Fungi. The three main groups of fungi all have members that are of value to man, as well as others that are injurious.

1. *Phycomycetes* (algalike fungi). A few of the molds in this group are used for curing cheeses. Many are parasitic and cause injury by attacking the potato (potato rot) or useful fishes or the grape (see Fig. 177). But some of them destroy flies and other insects of which we are glad to be rid. The ringworm parasite probably belongs here (see page 335).

2. *Ascomycetes* (fungi bearing spores in sacs). The useful yeast has already been described (Fig. 178). The edible morel (a very delicious "mushroom") and a few other usable fungi

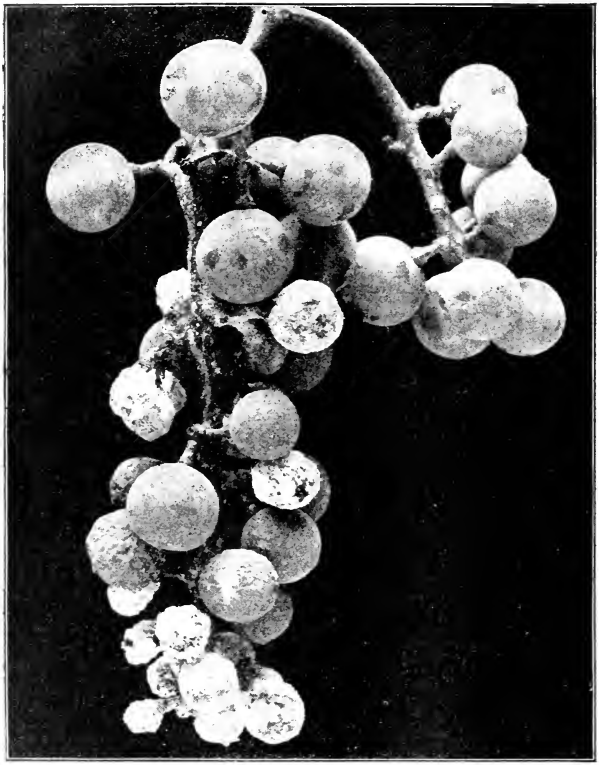


Fig. 177. Downy mildew on grapes

This fungus represents a large group of parasites that annually cause serious damage to many of our cultivated fruits and vegetables. (From Duggar's "Fungous Diseases of Plants")

belong here. There are many mildews and other parasites upon useful plants, as well as many that destroy dead organic matter, often causing serious damage to cloth or leather goods that are allowed to remain damp, and to railroad ties and cut lumber.

3. *Basidiomycetes* (fungi bearing spores in open). Most of the common toadstools and mushrooms are in this group, including the ones most widely used for food. There is no general distinction between edible mushrooms and poisonous ones; very often both kinds are found in the same genus. While it is dangerous to take any chances with forms that are not well known to be fit to eat, it is not difficult to learn to know the different species apart. Rusts and smuts are among the most destructive fungi and may ruin a whole season's crop in a short period. The various forms of bracket, or shelf, fungus usually live on dead trees but may be destructive to cut timber. The brown, fluffy pulp of these fungi is sometimes made into the punk which will hold a spark for a long time without bursting into flame. It is sometimes used in incense sticks and as an absorbent in fine dental work. It was formerly used as a tinder before matches became so common.

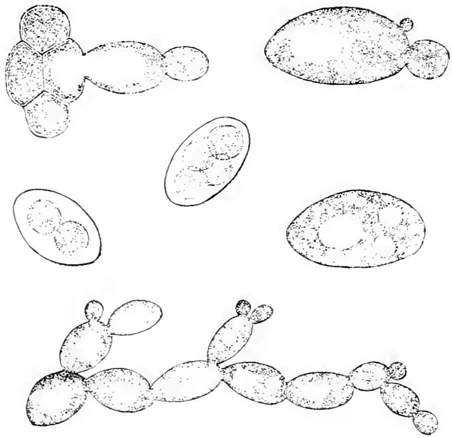


Fig. 178. Yeast plant

The cells of this plant multiply by pushing out buds. Under certain conditions the protoplasm of a cell divides into two and then four parts, which then can remain inactive for an indefinite time. These resting cells are called *spores*

320. Lichens. These curious partnerships between a fungus and an alga are found in all parts of the world. They probably play an important part in converting rock into soil. Iceland moss and reindeer moss serve as fodder for reindeer.

321. Mosses and ferns. The peat moss (*Sphagnum*) fills up bogs and swamps, gradually decays, and becomes converted into peat (see page 419). It can absorb much water and has been

used in emergencies as a dressing for wounds; large quantities were used in this way during the World War. When dry it makes a useful packing material, but is now used almost entirely for packing plants. Generally speaking, however, the mosses are of little direct use to us, although they are very interesting plants and probably play a part in the gradual conversion of the soil into a place suitable for higher plants.

The ferns in past ages reached gigantic size and probably furnished most of the fuel that we use today as coal. Aside from those gathered and cultivated for ornamental purposes the horsetails have been used for scouring, as the cells contain a considerable amount of hard silica, the same substance as sand. The club mosses, or "Christmas moss," were formerly of value because they furnished the lycopodium powder which may still be obtained in the drug stores. This powder consists of masses of *spores* (see page 470) which on account of an oily substance cannot get wet, and was therefore used as a coating for pills, to keep them from sticking together, and for many purposes that are now served by the mineral talcum powder.

322. Gymnosperms (naked-seed plants). The cone-bearing trees represent a family that is of great importance both for the timber that it furnishes and for the value of the standing forests. All our soft woods except the whitewood (tulip tree) and poplar come from this group—the pines, cedars, spruces, firs, redwoods, etc. The maidenhair tree, the ginkgo, has been introduced from Japan as an ornamental tree. The cycad, resembling the palms in some ways, links this group with extinct forms related to the giant ferns. Many of them are represented in the coal deposits in various parts of the world. The conifers furnish, besides timber, large quantities of resin and turpentine, and pulp for paper.

323. Monocotyledons. More than 25,000 distinct species of plants belong in this division, classified in some forty families. Half a dozen of these families are of marked importance to mankind, although each of the others may be related to our affairs in one way or another. While we shall note only the outstanding values or injuries that make members of each family

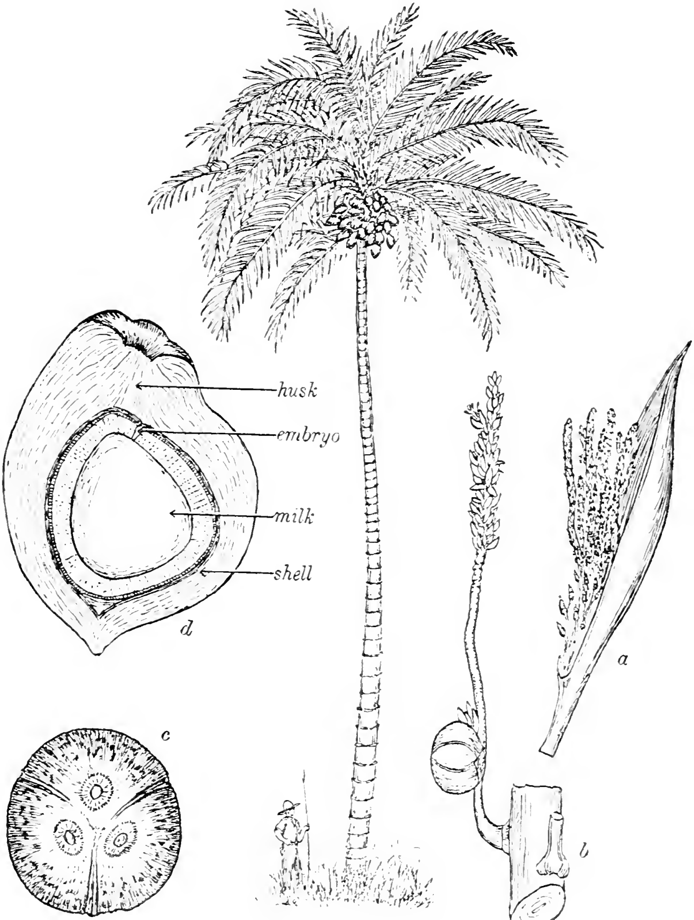


Fig. 179. The coco palm (*Cocos nucifera*)

This tropical member of the arum family reaches a height of 100 feet and furnishes food, shelter, and fiber for millions of people. The flower clusters, *a*, are grouped like those of Jack-in-the-pulpit (Fig. 26) with the pistil flowers near the base of the spike and the stamen flowers toward the tip, *b*. There are three carpels, *c*, in the pistil, but only one embryo ripens. *d* is a section of the fruit, showing the husk, the shell, the embryo embedded in the endosperm, and the hollow cavity containing the milk. Every part of the fruit, the stem, and the leaves is put to use in some way

important to us, we must remember that weeds (that is, uncultivated plants that spring up without our invitation) may become a serious problem wherever plants are cultivated, and that every family of plants may furnish pests.

1. *Grass family.* Most of our crop plants belong here. In addition to the grasses consumed by horses, sheep, and cattle directly from the ground or stored away as *hay*, we get from this family all our cereals: corn, wheat, oats, rye, barley, and rice. Sugar cane, the chief source of the world's sugar supply, also belongs to this family, as does the bamboo, which furnishes material for building and for utensils, paper, matting, furniture, parts of vessels and vehicles, and many other things for millions of people in Asia and the adjacent islands.

2. *Palm family.* The coco palm furnishes food, clothing, utensils, and such little clothing as they need to large populations in tropical islands. We use the flesh of the fruit, the fiber of the husk, and the oil of the fruit. The hard shell is sometimes worked into dippers and other vessels; it takes a high polish. The date palm is the staff of life to many people in northern Africa and Asia Minor. The sago palm furnishes masses of starch used as food the world over, since it can be conveniently prepared for storage and shipping. The rattan is used for making furniture, baskets, canes, and other objects that need a material that is tough, light, and flexible. The hard cellulose in the seeds of "vegetable ivory" is used for making buttons, knife and umbrella handles, and other things.

3. *Pineapple family.* This family is not related to the pines or to the apples. The fruit has become widely used because it can be shipped safely and because it can be easily canned. From the bast fibers in the leaves a very fine thread is prepared called *piña* in the Philippines. Only one member of this family is native to the United States, the so-called Spanish moss of Florida, which is prepared for stuffing furniture.

4. *Lily family.* Many plants of this family are cultivated for their beauty. On the more utilitarian side we have the common onion, the garlic, and asparagus.

5. *Banana family.* This is another family of plants that can supply nearly all the needs of the natives who depend upon it. The pulp of the fruit is prepared in a great variety of ways; it is dried and made into flour; it is mashed and fermented into drink; and it may be cooked, although most of us know it only in the raw. The bast of the leaves furnishes fiber that is put to many uses. The bast of manila-hemp leaves yields two grades of fibers, used for ropes, mats, bagging, sailcloth, binder for staff (a plaster-of-Paris mixture used for architectural models, and especially for the walls of temporary buildings), and as stock for coarse papers.

6. *Orchid family.* Most of us know of this family only from the curious specimens occasionally exhibited in the windows of flower shops, or from reading about the strange forms in the tropical forests. Many orchids are cultivated commercially for their beauty. The vanilla (see pages 50, 51) is used for flavoring material, but it is being replaced by synthetic substitutes.

324. Lower dicotyledons. Over 60,000 species of plants are known in this division, classified in about 180 families. All our important timber trees outside the pine family belong here. Every group furnishes many species that are of no known value, as well as many weeds and plants that furnish food and shelter for birds and other animals. Only the more important families will be considered.

1. *Willow family.* Thin twigs of many species of willow furnish the osiers, or rods, used in making wickerwork (see Fig. 190). The finest artist's charcoal is made of willow. The poplars furnish important wood and paper material.

2. *Walnut family.* Several species furnish edible nuts—black and English walnuts, butternut, hickory, pecan. All the trees furnish valuable hard woods, used both for heavy implements and for fine furniture and interior finish. The bark of hickory and the others furnishes valuable tanning material.

3. *Beech order.* The beeches, chestnuts, oaks, alders, filberts, and hazels are the important members of this group. Besides food, timber, and tanning material we get cork from some of the

oaks. The name *cork* is a corruption of the Latin *quercus,* which is the scientific name for all the oaks. We do not make much use of acorns except in some localities as fodder for pigs, but in Italy and other parts of Europe acorns of certain species are a considerable part of the food supply of man.

4. *Mulberry family.* The five important plants in this group are the mulberry tree, the leaves of which are the sole food of the silkworm; the fig plant; the India-rubber tree of the Eastern Hemisphere; hops; and Indian hemp. From a resin in this plant is prepared a dangerous poison *hashish,* which is sometimes used by the natives for its quieting effect upon the nerves; the after-effects of its use are said to be very bad.

5. *Buckwheat family.* In addition to buckwheat and rhubarb this family is chiefly notable for its pernicious weeds—smartweed, tearthumb, and bindweed being the most common.

6. *Goosefoot family.* This is represented in our garden truck by the beet and spinach. Next to the sugar cane (see grass family, p. 436) the sugar beet is the most important source of pure sugar.

7. *Crowfoot order.* The American native tulip tree, which furnishes the soft whitewood, and the magnolia, as well as the laurel, sassafras, cinnamon, and camphor trees, belong to this group.

8. *Poppy family.* Besides the many attractive flowers for which species of this group are grown, the drug *opium* is the most important product. This drug contains the alkaloid *morphin* (see page 420). The Chinese government attempted to wipe out the use of opium among the Chinese, and prohibited the production and importation of the drug; but commercial interests in India and other countries have continuously violated the law and made it difficult to save the masses of ignorant people from what is perhaps their worst enemy.

9. *Mustard family.* Many common plants come from this group. Besides mustard, from the seeds of which a medicinal product and the seasoning are prepared, we have the turnip, the radish, the horseradish, and the cabbage. There are many varieties of radish as well as of cabbage. Among the latter are Brussels sprouts, kohl-rabi, kale, and cauliflower. From an Oriental form, rape, a fine lubricating oil is produced.

10. *Rose family.* Besides the many varieties of attractive flowers and perfumes which we get from this family, we have also the most widely used cultivated fruits—apples, pears, plums, peaches, apricots, almonds, cherries, raspberries, blackberries, and strawberries. From the seeds of cherries, plums, and almonds a violent poison, prussic acid, is made. The woods of most of the trees make valuable material for small wares and furniture. The mountain ash belongs to this family.

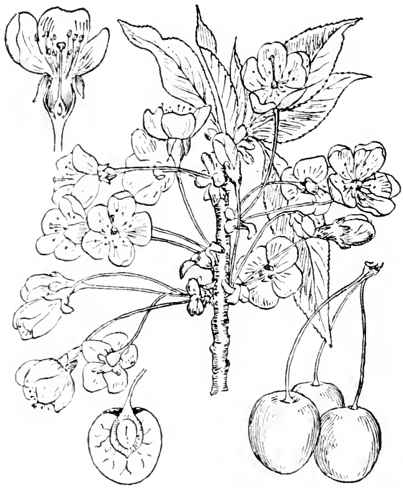


Fig. 180. The sour cherry (*Prunus cerasus*)

Many varieties of this member of the rose family are cultivated for the fruit

11. *Pulse family.* This includes the lowly clover and alfalfa and the stately acacia and locust trees. With the grasses and palms it is perhaps the most valuable single family of plants in the variety of uses to which its members are put. We get fodder for our cattle and substantial food for man—many varieties of beans, peas, lentils, "St. John's bread," and peanuts. They furnish proteins in larger proportion than any other plant material that we can use as food, as well as starch and oil. Gum arabic and gum tragacanth, of great value in the arts, are obtained from this group. Dyes are supplied by the indigo shrub and the logwood tree. *Copal,* a very valuable varnish, is dug from the ground in parts of South America and in Zanzibar. From the presence of bits of leaf and bark in the varnish, we know it to be the fossilized resin of certain plants of this bean family. This is a very successful family and accordingly has many species growing wild in all parts of the world.

12. *Flax family.* This small family has a distinguished member in the very useful flax plant. Besides the fiber we also use the seed, which furnishes a gum similar to tragacanth, the linseed oil which is so important in the mixing of paints, and the oil cake used as fodder for cattle.

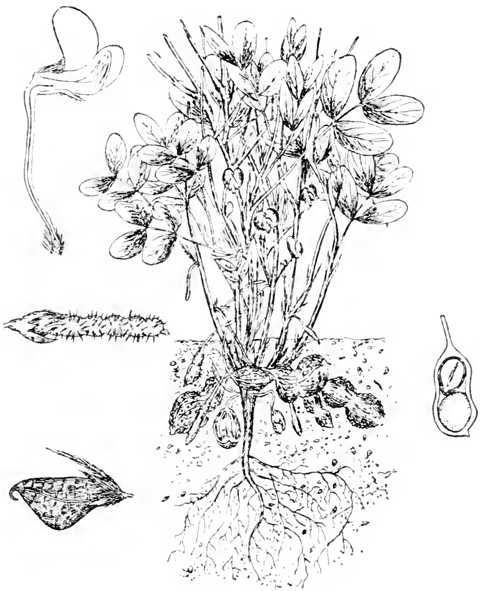


Fig. 181. The peanut plant (*Arachis hypogaea*)

This valuable representative of the bean family is a native of Brazil, but is now cultivated in most tropical and semitropical countries for its protein and fat. It is a good hay plant, and large quantities are raised for fattening hogs in the field. After fertilization the flower stalks elongate and the ovary works into the ground

13. *Rue family.* The citrus fruits (the lemon, orange, lime, citron, tangerine, and pomelo, or grapefruit) are of growing importance as cultivated commercial fruits. From the point of view of diet they are valuable for the acids, mineral matter, and vitamin C which they contain.

14. *Spurge family.* In addition to the beautiful poinsettia this family has three plants of great value to man. The South American rubber plant (*Hevea*) is of increasing importance as a source of rubber. Tapioca is obtained from the bitter cassava. The pulp of the crushed roots consists of a poisonous milky fluid and masses of starch. The starch settles out but contains a poisonous substance. The mass is then dried over fires on iron plates, to destroy the poison, and the starch breaks up into grains or small balls. The castor bean is of value because of its heavy oil, which serves as a lubricant in the intestine.

15. *Sumac family.* Some of the sumacs yield tannin; otherwise the family is noticed by most people as a nuisance, because of the poison ivy and the poison sumac.

16. *Maple family.* The maple is valuable as hard wood and is still a considerable source of sugar.

17. *Grape family.* Though a small family in number of species, the grape family has many varieties. The fruit is the basis of many kinds of wine as well as of soft drinks, and is used increasingly in this country in the dried form, as raisins.

18. *Mallow order.* In the cotton plant we have the most important single member of this group, since it supplies so large a part of the world's clothing, besides the valuable oil which is expressed from the seed. A gum similar to tragacanth is obtained from the roots of the marsh mallow. The linden tree and the jute plant represent another division of this order. The tons of chocolate and cocoa with which we enrich our candies and breakfasts come from the cacao plant. The seeds, or "beans," are taken from the fleshy pulp and exposed to a sweating, or fermentation, process and then dried in the sun. This seed contains a large amount of fat (which is used separately for soaps and for other purposes as "cocoa butter") and of starch. It is thus a nutritive material and not to be classed with such beverages as tea and coffee. These three all contain the same alkaloid (*theobromin*, *caffein*, and *thein*

Fig. 182. The cotton plant (*Gossypium*)

Many varieties of cotton are cultivated. New flowers keep opening up as the old bolls ripen so that harvesting goes on from July to November. The fiber of the seed pod is used not only for thread and cloth but for making celluloid, photographic film, explosives, surgical dressings, and other things

being different names for it), but tea and coffee give us only this alkaloid and their flavor.

19. *Myrtle order.* From this we get the Brazil nut (not a nut at all, but a seed), clove (dried flower bud), and pimento, or allspice (dried berrylike fruit).

20. *Parsley family.* The three homely garden plants parsley, parsnip, and carrot are a substantial part of our root crop. The three flavoring materials caraway, anise, and coriander seeds are really tiny, one-seeded, nutlike fruits. The ill-smelling drug asafetida is prepared from the milky juice in the root of a plant of this family. It is used in very small quantities in food sauces; but a slight excess would make most of us feel sick at the stomach. The water hemlock and poison hemlock belong to this family; it was the poison of the latter plant which is said to have been given to Socrates.

325. Higher dicotyledons. Nearly 50,000 species of plants in this division are arranged in over 50 families. Very few of these plants reach the dimensions of trees. Only the families of greatest practical value to mankind are indicated below, but thousands of species are of practical importance in each locality but of no importance in commerce or trade, since equally good substitutes are available in other regions. This applies to plants that supply food, as well as to those that furnish fuel, fiber, dyes, etc. It is equally true that in every region some species are considered pests or weeds, but may be cultivated for their beauty or for some peculiar quality in other regions.

1. *Heath family.* The cranberry and huckleberry and wintergreen are the best-known plants of this group. The mountain laurel and the sheep laurel, admired for their beautiful flower clusters, are poisonous in all parts and should be handled with some understanding. After gathering these plants, be sure to wash the hands thoroughly.

2. *Olive family.* Although both the fruit and the oil are used more in European countries than they are here, Americans are gradually learning to value the flavor and the other qualities. The white ash belongs to this family.

3. *Morning-glory family.* Sweet potatoes and yams are the most useful plants in this group and are likely to be used in increasing quantities.

4. *Mint family.* All the plants in this family contain more or less aromatic oil, and some of them are accordingly used as a source of flavoring material. The most familiar are sage, thyme, peppermint, and spearmint. A number are cultivated in gardens for their showy flowers.

5. *Potato family.* At present the tuber of the white potato is almost universally used as a source of starch in the diet. The fruit of the tomato plant, which we ordinarily speak of as a vegetable because it is not sweet, is also a very valuable part of the diet, and even when canned may serve as a source of vitamin C where fresh fruit and vegetables are not easily obtained. The red pepper and the egg-plant also belong to this family. Besides food, we get from this family tobacco and the valuable drug belladonna. One of the most dangerous of common weeds is the very attractive thorn-apple, or Jimson weed ("Jamestown" weed), which is poisonous in all its parts, containing the alkaloid *stramonium*.

Fig. 183. The potato (*Solanum tuberosum*)

This plant is a native of America, but has become widely cultivated as a staple source of starchy food. The tuber is an underground stem, the "eyes" being buds. In modern times greatly improved varieties have been developed; Luther Burbank was one of the leaders in this work

6. *Madder family.* The coffee bean at the grocery and quinine at the drug store are the most important products of this family. The dye madder was formerly of great importance in producing reds, but is being gradually replaced by coal-tar dyes.

7. *Cucumber family.* Many varieties of cucumbers, squashes, pumpkins, watermelons, cantaloupes, and gourds are familiar parts of the food supply in all parts of the world. Some of the gourds leave a hard, dry rind when the pulp and seeds are removed, and so may be used as vessels or containers. In the luffa the network of bast fibers left when the pulp dries and rots out furnishes a useful substitute for a sponge.

Fig. 184. The arnica plant (*Arnica montana*)

From the buds of the flower heads an extract in alcohol is prepared for medicinal purposes. It is common in upland meadows in parts of Europe and in the western part of this country

8. *Sunflower family.* In some respects this group may be considered the highest family of plants, since it has attained a very high degree of specialization of parts through division of labor, and a wide range of adaptation to all sorts of living conditions. One tenth of all the seed-bearing plants belong to this family; and while they never attain to great size, they have managed to occupy a large part of the earth's surface. They are of little value to us as food, lettuce and artichoke being the most commonly used. Chicory is often used as a substitute for or an adulterant of coffee. Dandelion roots and leaves are used to a slight extent. They are important factors in the weed crop at every season of the year that permits plants to grow; the dandelion comes out almost as soon as the frost goes, and the asters remain until frost kills the parts aboveground. Many composites are cultivated, the chrysanthemums being favorite

pets of breeders. The seeds of the sunflower are useful as feed for birds and poultry, but most of us find it too much trouble to reach the kernel. The teasel was formerly used by the wool workers to tease out the raw fibers, but that work is now done mostly by machinery. The thistle probably gets its name from this former use of its close relative. The goldenrod has acquired a bad reputation because many of the sufferers from hay fever are found to be sensitive to the pollen of these plants; but there are probably many people who can become sensitive to almost any pollen protein.

SUMMARY

1. While it is impossible to arrange all the known plants in a single series from lower to higher, we can so arrange the plants in many of the subdivisions; and the main divisions themselves may be considered as levels of development. In each branch the higher forms are distinguished by a greater specialization or division of labor among the organs, or a greater special adaptation to particular conditions of living.

2. In every main division of plants we find some that are useful to us either directly or indirectly, and some that are harmful to us either directly or indirectly.

3. Sometimes closely related forms may be both useful and harmful.

4. Sometimes a single species may have qualities or materials that are of use to us and other properties or materials that are harmful.

5. There is no general rule for distinguishing poisonous plants from those that are good to eat or harmless; sometimes a plant may contain both useful food and poison.

6. Many plants that are useful in one region are nuisances in another.

7. Plants that are useful at one period may become useless through the development of cheaper or better substitutes, or through changes in our way of living.

8. Plants that are of no use may become valuable through the discovery of their properties by scientific investigation or through the development of new needs.

9. Plants growing in one part of the world may come to be of value to people in another part of the world.

QUESTIONS

1. What is the most important crop plant in your region?

2. What part of this plant is of greatest worth? Why? To what uses can other parts of this plant be put?

3. What are the conditions that influence the size or the value of the crop from year to year?

4. What plants are cultivated in your region for beauty? What families do they represent?

5. What plant materials in your food are produced in your own neighborhood or state? Which ones have to be imported from other states? from Europe? from South America? from other places?

6. What plants furnish large parts of the raw material used by the industries of your community or neighborhood?

7. What occupations or industries rely upon plants for their raw materials? for their tools and implements?

8. What plants are injurious to the crops or materials raised or used in your community?

9. What plants are dangerous to the dairy industry? to wheat-raising? to the trees of your region? to the health of people?

10. What families of plants are represented in your region both by useful members and by pests?

11. What are the most objectionable weeds in your region? How can you recognize them? How can they be exterminated?

12. What poisonous plants are there in your region? How can they be recognized? What can be done to prevent their poisoning people? to cure the poison?

13. What plants are both useful and harmful to human interests?

14. What wild plants do you know that may have uses that have not yet been developed?

15. What wild plants in your region ought to be protected from extermination? Why? How?

16. How can we today make use of plants that have been dead for ages?

REFERENCE READINGS

CONN, H. W. Bacteria, Yeasts, and Molds in the Home, chap. ii, The General Nature of Molds; chap. vi, Yeasts in the Household.

DUGGAR, B. M. Fungous Diseases of Plants, pp. 483–498, Host Index of Fungous Diseases.

WATERS, HENRY J. Essentials of the New Agriculture, chaps. v–xv, xxxii–xxxiv, various cultivated plants.

Farmers' Bulletin 204, Cultivation of Mushrooms.

United States Department of Agriculture. *Bulletin 175*, Mushrooms and Other Common Fungi.

Farmers' Bulletin 1371, Diseases and Insects of Garden Vegetables.

United States Department of Agriculture. *Bulletin 1191*, Potash from Kelp.

Bureau of Fisheries. *Economic Circular 51*, Sources, Preparation, and Properties of some Algal Gelatines.

Farmers' Bulletin 720, Prevention of Losses of Live Stock from Plant Poisons.

United States Department of Agriculture. *Bulletin 706*, American Sumac, Tanning Material and Dyestuff.

United States Department of Agriculture. *Bulletin 1201*, Plants tested for Insecticidal Properties.

Farmers' Bulletin 663, Drug Plants under Cultivation.

Farmers' Bulletin 1184, Ginseng Culture.

Price List 44. Plants, Culture of Vegetables, etc. (from the Superintendent of Documents, Government Printing Office).

CHAPTER XLI

CLASSES OF ANIMALS AND THEIR ECONOMIC IMPORTANCE

Questions. **1.** How can we tell what animals are useful and what ones are harmful? **2.** Could we get along without animals? **3.** Are there common names in English for all kinds of animals? **4.** Are there common names for all the families, classes, orders, and main divisions? **5.** Why do we have Latin names for different animals? **6.** Why do we consider one class of animals higher than another? **7.** Why are not animals always able to protect themselves from their natural enemies? **8.** Why are not animals always able to get the food that they naturally need? **9.** Is it possible to exterminate any species of animal? Is it ever desirable to do so? Is it right to do so?

326. General relations. With animals as with plants a particular species may be related to us not because of any peculiarity of structure, habit, or chemical properties but because of the general fact that it is a living thing and so a link in the complex chain of interchange of materials (see Fig. 176). The protozoa, for example, are too small for us to eat, but they are not too small to serve as food for microscopic crustaceans, which in turn are devoured by larger animals, and these by still larger, until we come to fish that can serve us as food. Many animals, like many plants, serve in this cycle of life in the rôle of scavengers; that is, they feed upon the dead remains of other organisms and thus make dead matter at last available to man's purposes. This does not mean that every animal is of some use to mankind, either directly or indirectly, for that is not true of animals any more than it is of plants. Like plants, animals may be of indirect as well as of direct injury to us, to a very serious degree. A large part of the work which human beings do every year for the purpose of raising plants and animals is destroyed or spoiled by insects, by rats, and by other animals.

There are more species of animals than there are of plants, and there are also more main divisions, or branches. In the following descriptions only the more important groups are described.[1]

327. Protozoa. The protozoa live for the most part in natural waters, but many species are parasitic upon plants, others upon animals.

Some species have delicate lime cases; millions of these, falling to the bottom of the ocean and deposited in past ages, make up the chalk cliffs and lime deposits of today. Another group, bearing sandy shells, have in a similar manner contributed to vast deposits that are used today as grinding or rubbing materials. Compare Barbados earth to the fuller's earth deposited from plant skeletons.

We have already seen the importance of the malarial plasmodium and of the parasite causing yellow fever (see pages 322–325). Sleeping sickness and probably smallpox are also caused by protozoan parasites in man; many of the diseases of cattle and other domestic animals—Texas fever, for example—are due to protozoan parasites. A number of relatives of the ameba are found in the intestines of higher animals, and these sometimes cause serious disorders. The *pébrine* of silkworms, the problem that aroused Pasteur's interest in the causes of disease, is also due to a parasitic protozoön.

328. Porifera. The "pore-bearing" animals consist essentially of a skeletal framework built up by the secretions of the living cells and supporting layers of cells that are substantially alike (see Fig. 43). There is very little division of labor, but there is a great deal of common activity. The sponges of commerce are made of the horny skeletons of the sponge colonies (see page 430).

328. Cœlenterates. From a practical point of view the corals are perhaps the most important. It is through the growth of these colonial animals and the laying down of their lime skeletons that coral reefs and islands have been built up. Some of the coral structures are very beautiful; the pink coral of the Mediterranean is most highly prized and most extensively used for ornament.

[1] For the plan of classification see Chapter VII.

330. Worms. From a practical point of view worms are important because each of the groups contains members that are parasitic upon man or upon domestic animals (see Chapter XXXII). Some of the parasites of the flatworm group, living upon oysters and other mollusks, bring about the formation of *pearls*. For our own protection from many of these parasitic worms our foods must be properly cooked, and public agencies must prevent the passing of infected meat through markets or slaughterhouses.

331. Echinoderms. The one of most practical importance in our country is the starfish, which preys upon the oyster and has thus caused considerable damage to the oyster beds. In the Orient the trepang, or sea cucumber, is gathered for food.

332. Annelids. The segmented worms, of which the common earthworm is typical, are often used as bait by fishermen. The earthworm bores into the ground by swallowing bits of earth, which pass through the body and are thrown out as castings. In this way two results are produced: (1) the earth is brought from the lower layers to the surface, and (2) the soil is made more porous, allowing freer movement of water and air. In addition the earthworm consumes large quantities of organic matter in the soil, and some of the decomposition products are combined with the earth passing through the gut. It thus contributes to the fertility and to the mechanical qualities of the soil.

333. Arthropods. This is a very large branch of the animal tree, with its divisions fairly well marked. There are four important classes.

1. *Class Myriapoda* (thousand legs). The common house centipede is useful in that it kills small insects. It is perfectly harmless to man. Some other centipedes destroy earthworms and small snails, as well as insects, and their sting is very painful.

2. *Class Crustacea.* This class is represented by the lobsters, crayfish, crabs, and shrimps, which are useful as food; by the barnacle, which becomes a nuisance on the bottoms of vessels; and by the sow bug. Aside from the food which they yield, these animals are important factors in the *life cycle*, since some of them are almost microscopic in size, while some of the lobsters grow to be two feet or more in length. The crayfish sometimes cause injury to vegetation and to earth dams. Some of the crabs have become parasitic on fishes.

3. *Class Arachnida.* Most of the true spiders are useful because of their constant warfare upon insects. The ticks are altogether parasitic; the mites are responsible for the itch, for sheep scab, for the chicken-mite disease, and for damage to other domestic animals, as well as to greenhouse and orchard or field plants. In most cases the best thing for protecting plants is powdered sulfur. The jigger, or harvest mite, usually lives upon plants, but sometimes makes itself at home on human beings.

4. *Class Insecta.* The insects constitute the most numerous class of animals. The many species show adaptations to a

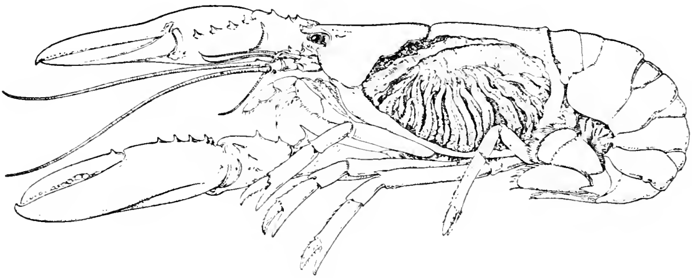


Fig. 185. How the lobster breathes

The featherlike gills of these crustaceans are protected by an extension of shell which incloses them almost completely. By the action of appendages connected with the mouth organs a constant current of water is made to pass over the gills through the space under the shield, moving from the back edge forward

remarkably wide range of conditions. From the human point of view they furnish many enemies, being in a sense our keen competitors for the possession of the earth (see Chapter XLIX); but we have among them also a few good friends.

In certain parts of Africa and Asia, as well as in South America, Mexico, and Central America, the natives are said to use various species of locust and caterpillar as food. Ants and termites, cicadas, the grubs of beetles, and the eggs of water beetles are also consumed. The Chinese sometimes eat the pupa of the silk moth after the silk has been removed from the cocoon. In so-called civilized countries the only insect that supplies food to man is the honeybee.

The wax obtained from bees is of great practical value, but it is coming to be replaced more and more by paraffin, which is obtained from petroleum. An insect product of growing importance, and one for which no satisfactory substitute has yet been found, is *lac*. Lac is used as a dressing for wood and other materials, as *shellac*, as a stiffening for felt in the making of hats, as an insulating varnish in electrical work, in the making of lithographer's ink and of sealing wax, and, in increasing quantities, in the manufacture of phonograph records. The cochineal, another member of the scale-insect family, furnishes a beautiful red dye; this was formerly used in large quantities, but, as we have seen, the anilin dyes are likely to replace substantially all dyes of plant or animal origin.

The whole silk industry rests upon the fiber obtained from the cocoon covering of the silk moth. Although the chemists have devised ingenious processes for making artificial silk out of cellulose, we shall probably continue to cultivate the silk moth for a long time to come.

Many of the beetles may be considered as useful, since they destroy large quantities of dead animal remains, as do also many of the ants. Thus they may be looked upon as scavengers; and a few of them, in the course of their predacious activities, devour forms that happen to be injurious to us, as the ladybug, which eats plant lice, or the Calosoma beetle, which keeps the gypsy moth in check.

We make direct use of very few insects. Many species are of indirect value as important links in that chain of life extending from decomposing organic matter at one end to the large useful animals, and human bodies, at the other. Many species of insects are essential to the propagation of various species of plants, since they are the sole agents in the distribution of pollen.

334. Mollusks. The three classes of mollusks (see page 84) are rather distinct. Many species among the gastropods, as well as among the pelecypods, are used for food in all parts of the world, both fresh-water and marine forms being available. Our most common molluscan food species are various kinds of clams,

oysters, mussels, scallops, periwinkles, and abalone. The shells of many of the bivalves (pelecypods) are used for making buttons, knife handles, and other small wares. The mother-of-pearl, or *nacre*, from the inner face of many shells, is used for ornamental purposes. Crushed shells are used to supply lime for chickens. The cuttlefish discharges a dark fluid into the water when startled or pursued; this is the source of *sepia*, a brown pigment used by artists. In former times a mollusk supplied the highly prized Tyrian purple, a deep-red pigment formed by the oxidation of some of the animal's juices. Squids and cuttlefish are used by fishermen as bait. It is from a bivalve that pearls are obtained (see section 330). On the whole, the mollusks are probably the most valuable of the invertebrate animals, but they are not all of value (see Fig. 4). The oyster drill is a small, snail-like animal that bores through the oyster shell and does considerable damage. Many of the land snails and slugs become serious pests, destroying garden and truck plants.

335. Vertebrates. The branch of animal life which includes the backboned animals has also a few rather rare forms that are not, strictly speaking, vertebrates, yet have many resemblances to them. Of these lower forms the lampreys and hagfish are important because they are sometimes parasitic on useful food fish, and the lancelet has been used to some extent as food in tropical islands. Outside of these lower forms, all the animals in this great division are arranged in five classes (see page 86). All these animals are of course a part of the general scavenger and food cycle. In each class we shall find large contributions to our food supply, fish, birds, and mammals being most important in this respect. In each class we shall find also animals that are of direct use to us in some way, the mammals and birds leading the others; and in each class we shall find some real enemies, the mammals again leading. Because of their importance we shall consider each class separately.

336. Fishes. The general form of the body shows adaptation to movement in the water; yet there are great differences in actual shape, from the nearly cylindrical eel to the flat skate

and flounder, and there are great differences in size, from little minnows, gobies, and anchovies, two inches or less in length, to the giant sharks, reaching from thirty to forty feet. While all fishes are water animals, they live under a great variety of conditions—in swift streams and quiet pools, near the surface of the sea and at great depths, in sunlit waters and in totally dark caverns, in fresh water, in brackish water, and in the sea, in hot, tropical ponds, and in water nearly cold enough to freeze.

The head is in most species continuous with the trunk, and the latter with the tail, although the end of the tail is usually

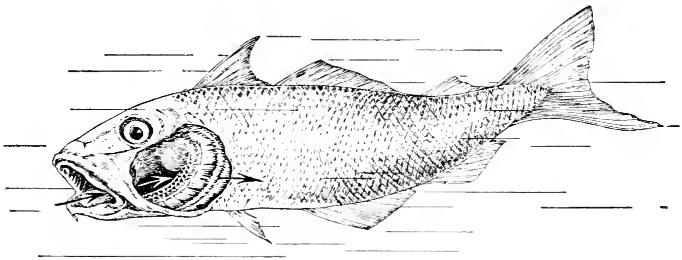


Fig. 186. How the haddock breathes

In the fishes the gills are arranged on arches along both sides of the pharynx. Water is taken through the mouth and passes over the gills and out again, as indicated by the arrows. In the bony fishes the gill slits are covered by a shieldlike plate, the *operculum*, which is free on the posterior edge. The bony fishes also have a swimming bladder, connected with the pharynx (see Fig. 78), which is apparently used partly for breathing (the blood vessels in the wall of the bladder being exposed to moist air) and partly as a means of raising or lowering the body in the water

expanded into tail fin or fins. The appendages are normally two pairs, pectoral and pelvic fins (see section 225); and there is usually also one fin along the back (dorsal) and one back of the anus on the ventral side; this is usually called the anal or ventral fin. Most fishes have an exoskeleton consisting of scales or spines, growing out of the skin. The bony fishes have a true jaw, and most species have teeth. The mouth is the only organ among fishes with which food or prey can be grasped, although many of them can fight viciously with their tails, their fins, and various outgrowths of the snout.

The eyes are similar to those of other vertebrates, but are generally very shortsighted. There are two nostrils, but these do not connect with the food tube, as they do in all the other classes of vertebrates, but end in odor sacs. There is no external ear, but the internal ear somewhat resembles that of the other vertebrates, including the semicircular canals, or balancing organs. In addition the "lateral line," which is easily distinguished in most of the familiar fishes, is well supplied with nerves and joins the brain close to the ear nerves. It is probably sensitive to certain vibrations in the water.

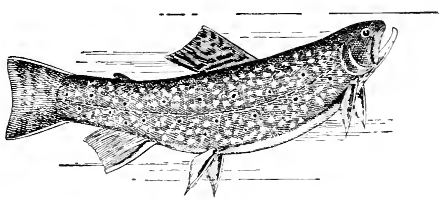


Fig. 187. Lateral line in brook trout

The line running along each side from the gill cover to the tail is made up of nerve end-organs that are sensitive to certain kinds of vibrations in the water

In common with all other vertebrates, fishes have blood consisting of plasma and white and red corpuscles. The blood is contained within the blood vessels, and the circulation is maintained by means of a *two-chambered* heart. This is in contrast to the three-chambered heart of the batrachians (see page 87) and the four-chambered heart of birds and mammals.

There are over 15,000 species of fish known; some 3000 species live in the waters of the United States. A very large proportion of these are fit for food, although not all of them are extensively used. Modern methods of preserving and packing food have made it possible to extend the use of marine fish to inland communities, and of seasonal fish to all parts of the year, and so on. In addition to the use of fish as food many species yield valuable oils; the cod and menhaden are the most important. The skin of some of the sharks is worked over into a hard, tough leather called *shagreen*, which is valuable for buffing and polishing. The eggs of sturgeons and a few other species are preserved in large quantities and eaten as *caviar*, which is

considered a great delicacy. The parts of fishes remaining after the food portions and oil have been removed are sometimes ground into a meal for feeding animals, and all wastes are useful as fertilizer. In many ponds the fishes help to keep down the mosquito nuisance by devouring the eggs and larvæ of the insects.

On the other side of the account, several species of fish are undesirable inhabitants of fresh waters, the pike and the pickerel being destructive of more valuable forms; and along the coasts many varieties of sharks are not only destructive to smaller fish, crabs, lobsters, etc., but sometimes attack men.

With growing populations and narrowing margins of usable soil more and more attention has to be given to the utilization of food supplies from the waters of the earth. The United States Bureau of Fisheries is constantly investigating problems connected with increasing fish supplies, protecting food fishes, introducing new forms, restocking lakes and rivers, and so on.

337. Batrachians. The name *amphibians*, which is sometimes given to this class, suggests that they have two modes of life, one in the water and one in the air or on land. This refers to the breathing, which is always by means of gills in the young stage and (in the more developed forms) by means of lungs in the adult stage. The name *amphibian* does not apply to all of them, for there are some that continue to breathe by gills all through life. The metamorphosis characteristic of the development in the frogs and salamanders (see section 227 and Fig. 138) is absent in a few forms, which continue in what we should call the tadpole stage throughout life; but among some of these it is possible to force a further development by reducing the moisture.

There are three main groups of batrachians: (1) those that have no legs and so resemble snakes without scales; (2) those that have tails as well as legs—newts, salamanders, etc.; and (3) those that have legs but no tails in the adult stage—frogs and toads. None of the living forms grow to be very large, the giant salamander of Japan being perhaps the largest, attaining a length of from four to five feet; it is used as food. In ancient

times, however, there were considerably larger forms. The limbless batrachians comprise only a few species, confined for the most part to tropical regions. The other two groups are widely scattered over the earth, but no batrachians live in salt water. They show a wide range of adaptation in organs of locomotion, in color, in feeding habits, and in resistance to extreme heat or extreme cold; for they will curl up and sleep in the mud when it gets too warm, and curl up and sleep in the bottom of a pond or a stream when it gets too cold.

Most batrachians are harmless and are of practical value to us in their greedy feeding upon insects, worms, small crustaceans, and fish. In Europe the legs of frogs are widely used for food, while in this country they are considered a delicacy.

338. Reptiles. These animals are all air-breathers. Although they resemble the amphibians in some respects (especially in the similarity of form between lizards and salamanders), they undergo no metamorphosis after leaving the egg, and they always have skeletal structures in the skin, which batrachians never have. They vary in form and size from small, wormlike snakes, only a few inches long, to the giant turtles weighing half a ton, and the alligators and crocodiles, which may reach a length of thirty feet. In past ages there were many more reptiles, and they attained much greater size. Reptiles also show a great range in degree of development and differentiation. Some of the snakes have a large number of substantially similar ribs and vertebræ (about four hundred of the latter in some species), whereas in the turtles and crocodiles the number is definite and each is distinct in its structure and in its relations to the body as a whole. While most reptiles are tropical, they range pretty far into the temperate regions; they occupy salt water as well as fresh water; most of them live underground, though a few live in trees. Reptiles are cold-blooded, and most of them have a heart resembling that of the batrachians; among the crocodiles there is at last a four-chambered heart.

In certain respects, which appear most strikingly in the skeletons, and especially in the fossil skeletons, reptiles resemble

birds even more than they do amphibians. The scales on the legs of birds, the beaks of turtles, and the bony plates around the eyes are some of the similarities.

From an economic point of view most reptiles are harmless and even useful in that they destroy insects, mice, snails, and other pests. Some are valuable as food, particularly the turtles in this country and the iguana (lizards) in South America. The tortoise shell is a valuable material for combs and other ornamental objects; the skin of crocodiles, alligators, and some snakes is made into a tough and beautiful leather. There are a few poisonous snakes. In this country four are worth noting. The copperhead and the water moccasin, as well as the rattler, can be recognized by the head, which is rather distinct from the trunk and somewhat triangular. The coral, or bead, snake of the southeastern states is recognized by the bright red bands with yellow borders. Antitoxins have been prepared as effective remedies for snake bite, but they have to be used very soon if they are to be of any help. In India poisonous snakes take a large toll of human life every year, but in this country they are really not very serious.

339. Birds. There are nearly 20,000 species of birds in the world, and nearly 1000 in North America. They are warm-blooded—warmer than mammals even—and are characteristically covered with *feathers*. There are three kinds of feathers in birds: (1) down; (2) contour feathers, which cover most of the body; and (3) the quill feathers. In addition there are hair-like bristles about the beak. All birds lay eggs which hatch outside the mother's body, but usually with the help of heat furnished by one or both parents. Living species of birds are without teeth (although extinct forms had teeth), and the jaws are typically beaks. There is a wide range in size, from humming birds hardly two inches long to ostriches standing eight feet or more in height and averaging four hundred pounds. As with other vertebrates, fossil remains show that larger forms existed in past ages. The birds also show striking adaptations to a great variety of living conditions.

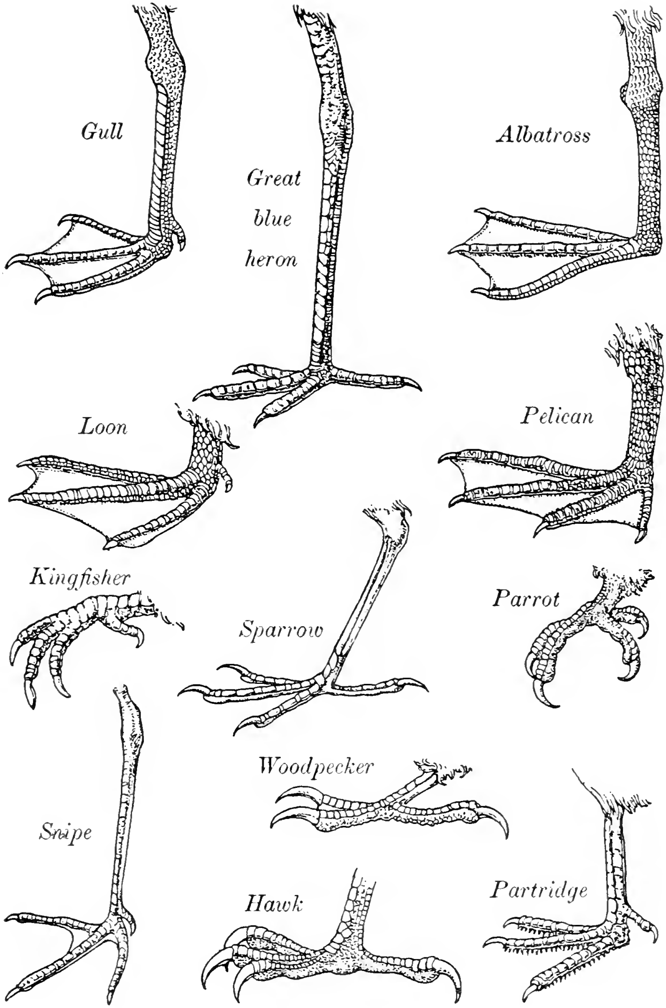


Fig. 188. Specialization in the legs of birds

Although the legs of all birds are constructed on the same general plan, there are many distinctive features that correspond to the different habits of life. There are the webbed toes of water birds — gull, loon, albatross, pelican; the long legs of wading birds — heron; the sharp claws of birds of the predatory habit — hawk. Contrast the climbing foot of the woodpecker with the perching foot of the parrot and the ground foot of the sparrow or partridge

There is a striking differentiation between the anterior and posterior appendages (wings and legs) (see Fig. 188); and there are differentiated forms of beaks as well as of legs (see Fig. 189). The eye is very well developed, as is the sense of hearing. The sense of smell, while present, is not particularly keen. Related to the care of eggs and young are many specialized instincts connected with nest-building and food-gathering.

The poultry and eggs produced in this country and sold for food every year are valued at over $500,000,000. To this must be added the quantities consumed by the people who raise them, the imported bird products, and the game birds used as food, the value of which it is practically impossible to estimate. Imported feathers and downs come to about $8,000,000 a year.

The most valuable organic fertilizer consists of *guano*, which is the refuse of millions of birds, accumulated through a long stretch of years on various islands off the coast of South America.

Of all animals the common birds yield most pleasure to man, with their song and chatter, their beautiful appearance, and their interesting activities; but the greatest importance of birds to man is found to lie in their relation to insects and weeds. They are thus significant not so much by what they produce for us, even if we make full allowance for the food and feathers and fertilizer that they yield, as by the help they give us in conserving or protecting our crops (see Chapter L).

340. Mammals. The name *mammal* comes from a word meaning breast and refers to the milk glands by means of which animals of this division nourish the newborn young. The class is also characterized by a skin covered with *hair*, and by a separation of the body cavity into thorax and abdomen by the *diaphragm* (see Fig. 124).

Our most important protein foods come from the hoofed animals—not only meat but milk and its derivatives and modifications. The most useful single animal in relation to our clothing is the sheep. The most useful animal in relation to work and transportation is the horse. Our furs are all mammalian prod-

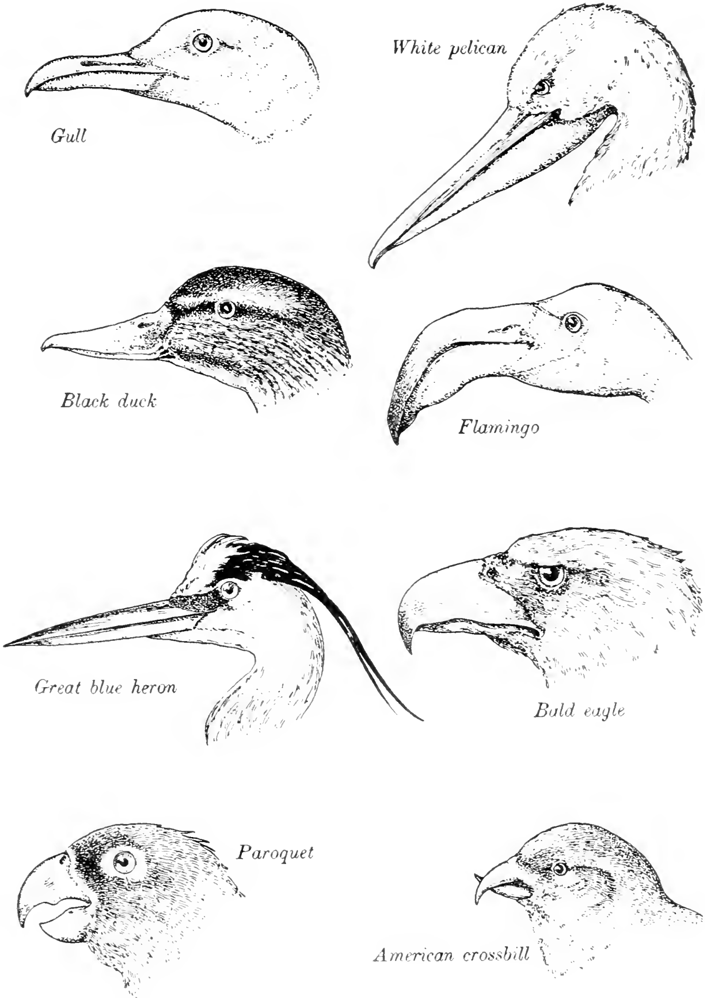


Fig. 189. Specialization in the beaks of birds

A beak is a beak, but the bill of a sparrow is different from that of a stork. Many of the distinctive features found in the beaks of different species of birds correspond to specialized ways of getting food or to the character of the food eaten

ucts, as is nearly all of our leather. The hairs of mammals are used in a great variety of ways, and appear daily in our toothbrushes and other cleaning devices, as well as in paintbrushes and artists' brushes. Quills are modified hairs. The bones of mammals are converted into buttons and handles for knives, umbrellas, and other small objects, as is also the horn of various hoofed animals. Ivory is considered the most valuable of these hard materials and is obtained from tusks (the teeth of elephants). A number of the smaller mammals destroy insects and so help in keeping these in check. Of the domestic mammals those that are brought to the large packing houses are systematically used up to the last hair; every part of the steer or sheep or pig is used for something or other; finally, the blood and the trimmings that are of no other direct use are converted into fertilizer or feed for poultry.

The mammals have rendered us splendid service as experimental material; with their aid we can discover important facts about the workings of our body, and especially about the interaction between parasites of various kinds and the human body. The smallpox vaccine which we get by means of the calf, the antitoxin for diphtheria by means of the horse, and the treatment for rabies by means of the rabbit tell only part of the story. The guinea pigs have been of the greatest help in these studies and experiments, because their blood, in its reactions to parasites, is in many ways like human blood.

From the very fact that mammals are efficient animals we should expect to find many enemies among them. All the wild animals that prey upon human beings (wolves and some members of the cat family) or upon our domestic animals are gradually being pushed farther and farther from the edge of our clearings in the world's wilderness, although in parts of Africa and of Asia they still remain formidable enemies. But we have not succeeded in getting rid of our worst mammalian enemy—the rat. This animal destroys more buildings, earthworks, stored grain, prepared food, clothing, and other organic material than any other species. Moreover, in its filthy habits

the rat scatters bits of food that may undergo decay, and distributes the plague and parasitic worms. It sometimes attacks poultry and even larger animals. Of all the mammals the rat should be exterminated first. The problem is partly one of protecting our premises and warehouses from the entry of the rat, and partly one of trapping, poisoning, and starving it. The larger owls are among the best rat exterminators, but they can never meet the situation without our help.

On the other side of our mammal problem is the fact that many of the native fur-bearing animals are threatened with extinction through excessive trapping and hunting. The game laws of the various states are designed to protect these mammals and to preserve them for the continuous use of human beings. In some parts of the country it will be necessary to do more than pass game laws. Already steps are being taken to establish game preserves in which the animals will have an opportunity to multiply and eventually perhaps to restock other regions.

SUMMARY

1. There are more branches, or principal divisions, in the animal world than in the plant world.

2. It is impossible to arrange all animals in a continuous series from lower to higher, but nevertheless some of the branches we can recognize to be higher than others because the individuals have more complex structures, higher degrees of division of labor, and more highly specialized adaptations of structure to function.

3. In each branch we can find increasing complexity, division of labor, and specialization of structure.

4. In all the branches we find the same essential functions performed; in most branches we can find homologous organs performing different functions.

5. All animals take part in the general cycle of life whereby the materials of protoplasm are constantly moving on from one organism to another.

6. In every branch of animals are some of which we can make use, and in every branch are some that are directly or indirectly injurious to us.

7. Sometimes a single species may have qualities or materials that are of use to us, and other properties or materials that are harmful.

8. Animals that are harmless or injurious in one region may be useful in another, and vice versa.

9. Animals that are useful may become injurious through too great increase in numbers.

10. Animals that are useful may become useless through the development of cheaper or better substitutes for what they yield us, or through changes in our ways of living.

11. Animals that are of no use may become useful through the discovery of their qualities by scientific investigation or through the development of new needs.

12. Animals of value may be in danger of becoming extinct.

13. Animals in one part of the world may come to be of value to people in a different region.

QUESTIONS

1. What are the most important native (uncultivated) animals in your region in relation to human health?

2. What are the most important uncultivated animals in relation to our food supply?

3. What are the most important uncultivated animals in your region in relation to our clothing or other material needs?

4. What are the most important cultivated animals of your region in relation to human food?

5. What are the most important cultivated animals in your region in relation to clothing and other material needs?

6. What are the most important cultivated animals of your region in relation to human health?

7. How do you measure the relative importance of different animals?

8. What parts of the different animals are used as food besides the flesh (muscle)?

9. What useful animal products can be replaced by plant materials? by mineral materials or synthetic products?

10. What dangerous animals are there in your region? What can be done about them?

11. What useful animals in your region are dying out? What should be done about them?

12. What useful animals in your region depend for their existence upon other animals? How?

13. How can an animal be both useful and injurious?

14. What sources of animal food are worth cultivating on a larger scale than heretofore?

15. What animals not cultivated are worth cultivating?

16. What legal restrictions are there in your state upon the destruction of fish? of birds? of mammals? of other animals?

17. What class of arthropods do you consider the highest? Why?

18. What class of mollusks do you consider the highest? Why?

19. What group of batrachians do you consider the highest? of reptiles?

REFERENCE READINGS

REESE, A. M. Outlines of Economic Zoölogy, various chapters for special reports.

WATERS, H. J. Essentials of the New Agriculture, chaps. xvi–xxiii.

United States Department of Agriculture. *Bulletin 416*, The Red Spider on Cotton.

Farmers' Bulletin 447, Bees.

Bureau of Fisheries. *Economic Circular 20*, Caviar.

Bureau of Fisheries. Annual Report, 1919, Appendix 7, Freshwater Turtles a Source of Meat Supply.

United States Department of Agriculture. *Circular 135*, Maintenance of Fur Supply.

United States Department of Agriculture. *Bulletin 1078*, Beaver Habits and Possibilities of Beaver Farming.

United States Department of Agriculture. *Bulletin 1049*, Game as a National Resource.

Farmers' Bulletin 1055, Country Hides and Skins, Skinning, Curing, and Marketing.

Farmers' Bulletin 1247, Moles as Pests and as Fur-Bearers.

Farmers' Bulletin 896, Rats and Mice.

Farmers' Bulletin 1397, Mouse Control in Field and Orchard.

Farmers' Bulletin 1302, How to get Rid of Rats.

Price List 21. Fishes.

Price List 39. Birds and Wild Animals.

CHAPTER XLII

MULTIPLICATION IN PLANTS

Questions. 1. How can plants that have no seeds be multiplied? 2. What are the different ways in which the number of plants of any kind can be increased? 3. Can plants of any species be multiplied in more than one way? 4. Is it better for a plant to produce large seeds or small seeds? 5. What kinds of plants produce most seeds? 6. Of what use is the fruit to the plant? 7. From what dangers do young plants need to be protected? 8. How are young plants protected from different kinds of danger?

341. Cell division. We have seen that living cells often end their existence by *dividing*, each cell giving rise to two new ones (sect. 48), and that they begin their existence by the division of a preëxisting cell. In one-celled plants and animals cell division is a means of *reproduction*, since it gives rise to new individuals. In many-celled plants and animals cell division is a factor in *growth*, since it results in a greater mass of living body. It is also a factor in *development*, since at certain points it gives rise to new kinds of cells and tissues. Under certain conditions cell division in a many-celled plant or animal may result in the *healing* of wounds, breaks, or injuries. And, finally, under certain conditions cell division in many-celled plants and animals may give rise to new many-celled individuals.

Adventitious roots on a begonia leaf or a strawberry stem result from cell division, and the process finally brings about the formation of a new plant. This kind of process is the basis of plant *propagation* and is of great practical importance. There are many useful plants that bear no seeds; for example, the banana, the pineapple, the navel orange, and seedless grapes and apples. New growths of these varieties are obtained by setting out pieces of stem so that complete plants at last develop

from these fragments. In multiplying certain cultivated plants that do bear seeds it is sometimes found more practicable to use this vegetative propagation than to depend upon seeds. This is usually the case in "layering" raspberries—bringing a stem over until it touches the ground and then keeping it in this position until it establishes a hold by means of adventitious roots (p. 117).

Fig. 190. Pollarded trees

White poplars (*Populus alba*) pollarded to supply building poles in Chinese Turkestan. Pollarding is the pruning, or trimming, of the branches of a tree so as to make more twigs develop. (From a photograph by F. N. Meyer, of the United States Bureau of Plant Industry)

Many plants bear upon their stems more buds than normally develop into twigs or branches. When the stem is injured or cut, some of these resting buds may begin to grow. We take advantage of this fact when we wish to get many small twigs rather than a few large branches (see Fig. 190).

342. Grafting. Through continued cell division it is possible for two surfaces of living cells to grow together *even where the*

two parts belong to different plants. Such growing together is called **grafting** and is extensively utilized in horticulture (see Fig. 191). The *scion*, or twig grafted upon the stock, produces leaves, flowers, and fruit of its own kind, uninfluenced by the

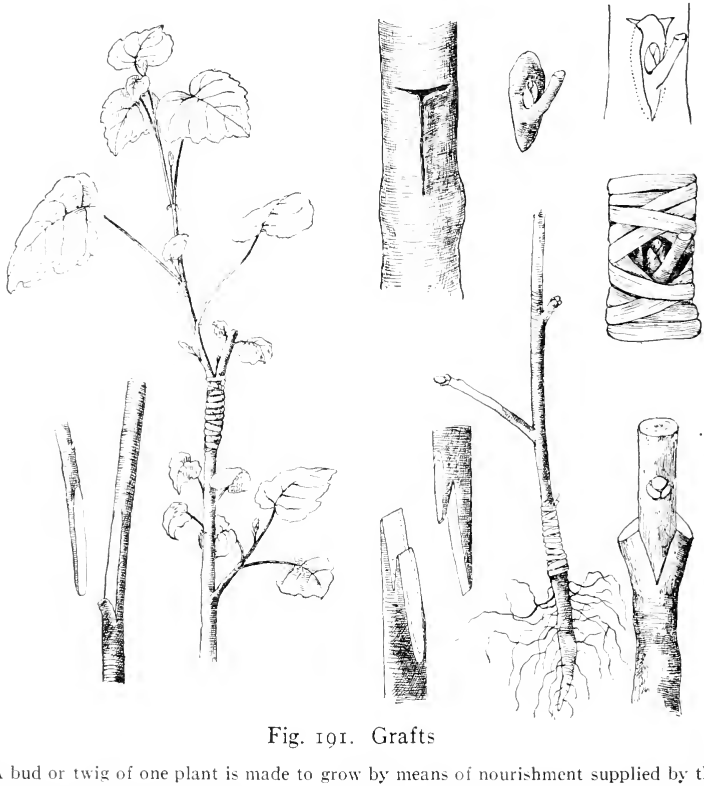


Fig. 191. Grafts

A bud or twig of one plant is made to grow by means of nourishment supplied by the root or stem of another plant. The root or stem supplying the nourishment is called the *stock*; the bud or twig grafted on the stock is called the *scion*. The figure shows stem, bud, and root grafts

character of the stock; that is, the protoplasm determines the character of its products, rather than the food which it receives.

In recent years a new application of grafting has been made in tree culture. Where orchard trees have been *girdled* (p. 120)

by mice, rabbits, mechanical injury, some insect borer, or fungal disease, they have had to be abandoned. There is no way by which the removed bark with its phloëm vessels can be replaced after the destruction of the cambium. By means of bridge grafting, however, thousands of trees are being saved (see Fig. 192).

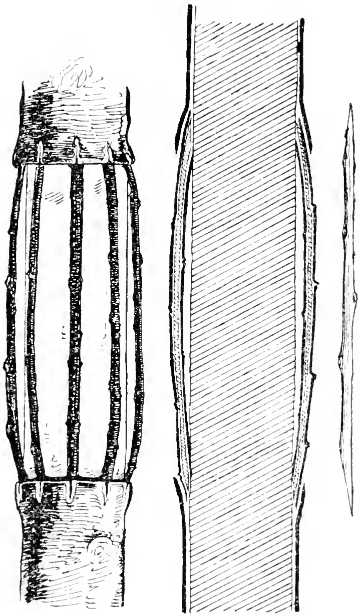


Fig. 192. Bridge grafting

Where the bark has been destroyed in a complete ring around the trunk, the cambium layer above the injury can be connected with the cambium layer below the injury by means of twigs that are trimmed down to slip under the bark and so *bridge* the gap. The growing layers of the young twigs and of the old stem grow together where they touch, and in time the vessels, or ducts, furnish complete communication between the roots and the upper parts of the plant. By this process many valuable orchard trees are now saved for useful service

343. Budding. In some one-celled plants new cells are produced by means of outgrowths or swellings, which have been compared to "buds" on trees. In the yeast plant (Fig. 178) this can be easily seen. The bud continues to absorb nourishment from its surroundings and to grow. It may put forth buds on its own surface or it may drop off and continue growing and budding apart from the mother cell.

The buds on the twigs of large plants are condensed shoots; each consists of stem and leaves with modified leaves or scales which serve as protection. Single buds with enough of the bark to include the cambium may be removed and grafted on a stock (Fig. 191). In propagating potatoes, pieces of the underground stem, or tuber, are used; the new plants grow from the "eyes," each of which is a complete bud, containing stem and leaves.

344. Spores. The term *reproduction* is sometimes reserved for processes in which the plant (or animal) gives rise to a *specialized* cell that can grow into a new individual. The simplest of such specialized cells are **the spores.** In ordinary cell division new individuals arise, but each of the new cells is just like the mother cell, and this mother cell at the time of division is apparently the same as any growing cell. In the yeast plant, when the conditions for growth are no longer favorable (for example, extreme temperature and lack of food or of water), the protoplasm in a cell shrinks up and divides into two parts, and each of these divides again. The original cell wall may become somewhat thickened. In this condition the protoplasm may resist drought or cold indefinitely; and when conditions are again suitable, it may absorb water, and each of the four units may start a new vegetative series. These special resting cells are *spores*. Nearly all plants produce spores, and usually in large quantities. Fungi are widely distributed because their numerous and very small spores are easily scattered as dust by the winds, as well as by insects, birds, and other animals. The pollen grains in flowering plants (sect. 35) are spores. In mosses the spores are borne in neat little capsules on the ends of slender stalks on top of the leafy stem. In ferns we can find groups of tiny spore cases, usually on the under surfaces of the fronds, in the form of dark dots (see Figs. 40 and 41).

345. Conjugation. In many plants, including fungi and algæ, there occurs a process whereby the contents of two cells (that is, the protoplasm) unite to form a new cell that may later start another generation. In the *Spirogyra* (the common pond-scum, or frog spit) the individual cells are all alike and almost wholly independent of each other. Each cell has chlorophyl and is capable of absorbing what it needs and manufacturing its own food. Under certain conditions these cells grow in length and divide across the middle so that in the course of a few sunny days in the spring a pond may become covered over with millions of the green threads. Under conditions of darkness and low temperature, growth cannot take place, since chlorophyl cannot then produce food; but as the threads become tangled in the water two cells lying opposite each other may put forth budlike outgrowths which meet. The protoplasm of one cell then passes over into the other, where they unite and form a new kind of cell (see Fig. 193). This cell is like a spore in being

able to start a new growth and in being able to await favorable conditions for growth. It is unlike a spore in being produced by the union, or **conjugation**, of two preëxisting cells, not by a *division*. Conjugation takes place in the black mold and many other fungi, as well as among many of the simpler algæ.

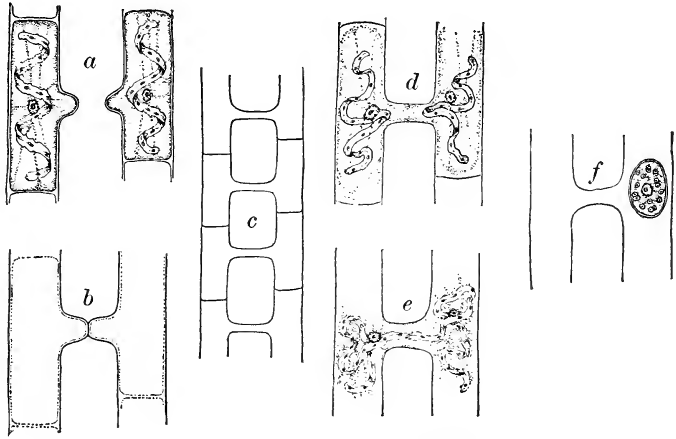


Fig. 193. Conjugation in *Spirogyra*

Cells lying close together put forth processes, or projections, toward each other, *a*. As these processes finally come in contact, *b*, the two threads with their crosspieces have the appearance of a ladder when looked at through the microscope, *c*. The cell walls at the points of contact are dissolved, probably by the action of a ferment, and there are thus formed continuous passages between the cells of one thread and the cells of the opposite thread, *d*. In the meantime, however, changes have been taking place inside the cells. The spiral ribbon of chlorophyl seems to break down, *d*; the mass of protoplasm in each cell draws away from the cell wall; and the protoplasm from one of the cells of each pair moves into the connecting tube and passes completely into the opposite cell, *e*. Here the two masses of protoplasm unite into one, and a thick cell wall is formed around the new combined protoplasm, *f*. The cell with the thick wall, inside the old dead cell wall, may apparently remain in resting state indefinitely, or may begin the next day to put out a thread of new *Spirogyra*, giving rise to millions of cells in the course of a few days

The cells which take part in conjugation are called **gametes**, from a Greek word meaning "to marry," that is, to join, or unite with. The cell which is formed by the union of the two gametes is called a **zygospore**, that is, a spore resulting from a joining, or yoking together. We may call it **zygote** for short.

346. Fertilization. In some of the seaweeds and other classes of plants, gametes are produced in special organs or on special parts of the plant body. This shows a division of labor between vegetative and reproductive regions or structures. There is a further tendency for the two gametes that take part in conjugation to become different from each other. In the bladder wrack, or rockweed, which is common on our coasts, some of the bladders on the tips of the fronds bear organs that discharge

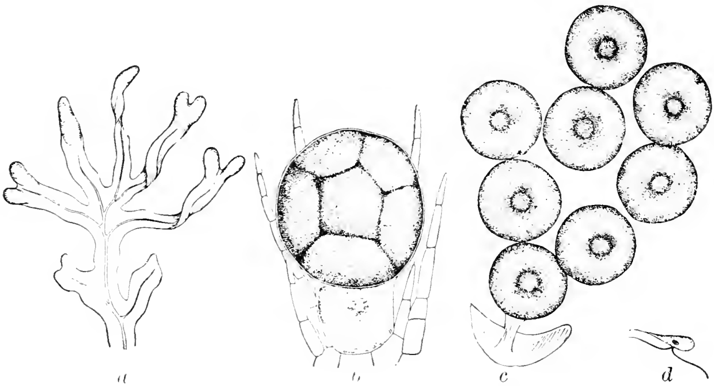


Fig. 194. Reproduction in rockweed, or bladder wrack

a, expansions of the rockweed containing the gamete organs; *b*, section of an egg-bearing organ; *c*, the large gamete, or *egg*, with large, distinct nucleus and food granules; *d*, the small gamete, or *sperm*, having the shape of a pear and bearing motile cilia. Sperms swarm around an egg until one of them unites with the egg. After the conjugation the zygote develops into a new individual

round cells into the water (see *a*, *b*, and *c*, Fig. 194). Other swellings bear organs that throw out tiny cells, somewhat pear-shaped, which carry two fine swimming threads, or cilia, on the side (see *d*, Fig. 194). The smaller swimming cells cluster around the large one until one of the small ones conjugates with the large one. The zygote then divides and starts a new rockweed. Where the two gametes are quite distinguishable, the conjugation is sometimes called *fertilization* (see section 35).

347. Male and female. Where the two gametes are so unlike, they are distinguished by special names. The large gamete is

sometimes called the **oösphere** or the egg cell; the small one is called the **spermatozoid** or the sperm cell. We sometimes call the large gamete, or egg cell, the *female*, and the smaller, or sperm, cell the *male*.

Most of the familiar plants and animals reproduce by means of male and female gametes, forming zygotes. This kind of reproduction is called **sexual** reproduction, in distinction from reproduction by spores, which is called **asexual** (that is, without sex), and in distinction from vegetative **propagation**.

There are many species of animals and plants that reproduce both sexually and asexually.

348. Flowers. If we recall the steps in the formation of seeds in flowers, we can understand the meaning of some of the structures and processes from a new point of view. The pollen grains and the embryo sacs in the ovules are considered spores. The changes that take place in the protoplasm of these two structures lead to the formation of gametes. One of the nuclei at the tip of the pollen tube (sect. 35) corresponds to the male gamete, or sperm cell. One of the nuclei resulting from the cell division inside the embryo sac corresponds to the female gamete, or egg cell. The fusion of these two nuclei is the essential step in fertilization; it is a *union of gametes*. The resulting nucleus is a zygote and proceeds at once to divide, starting a new plant. After cell division has proceeded for some time, the embryo, or young plant, shows differentiation of parts into shoot and root (hypocotyl, cotyledons, and epicotyl). The seed which results from the ovule is thus the embryo, belonging to one generation, plus the coverings, belonging to the *parents of the spores*. The parent of the pollen is of course not present in the tissues of the seed, but the parent of the embryo sac furnishes not only the protective coverings but also the stored food material, as well as all the food which nourished the embryo from the moment the zygote was formed to the time when the seed is ripe.

349. Fruit. The fruit, which is derived chiefly from the ovary, is significant in the life of the plant only for its relation to the succeeding generations. It is commonly a protection of the young plant while the seeds are ripening; and it is often in different ways an aid in the distribution of seeds after they are ripe (see Figs. 34 and 195).

Many fruits are covered with spines; others have hard or tough coverings or shells; still others contain bitter or acrid substances, which probably prevent their being eaten. Seeds that become separated from the fruit are frequently tough-skinned or are covered with some other protective layers.

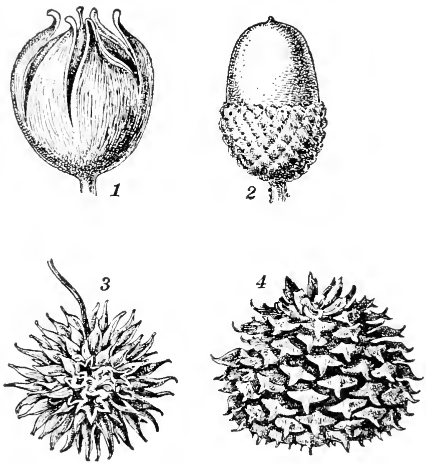


Fig. 195. Mechanical protection of seeds

1, bitternut (*Hicoria minima*), of the walnut family; *2*, chestnut oak (*Quercus prinus*); *3*, sweet gum (*Liquidambar styraciflua*), of the witch-hazel family; *4*, table-mountain pine (*Pinus pungens*)

To be in a position to perform its functions in the propagation of the species a seed must *get out* and *get away*—and the farther away the better, in most cases.

In many common plants the seeds escape from the parent through the splitting open of the ripe fruit along definite lines or through definite openings. The pods of the bean family and the evening-primrose family illustrate this *dehiscence*, and the poppy furnishes a good example of the formation of pores (see Fig. 197).

Fleshy fruits often drop off, carrying the seeds with them, and the seeds escape when the fleshy part of the fruit is eaten by some animal or rots (that is, is eaten by some plant).

Many fruits, however, do not permit the seeds to escape; the fruit and the seed are so closely united that they constitute a structure which acts as a whole, as in the grains, the nuts, and the nutlets of the dandelion family (Fig. 196).

350. Seed distribution. In their dehiscence many fruits open so suddenly that they shoot the seeds to a distance of a yard or more. This shooting is commonly brought about by the rapid

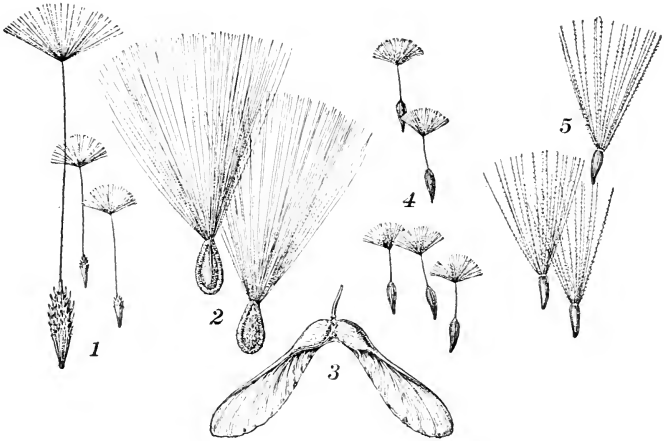


Fig. 196. Seeds scattered by the wind

1, dandelion; *2*, milkweed; *3*, white maple; *4*, prickly lettuce; *5*, thistle

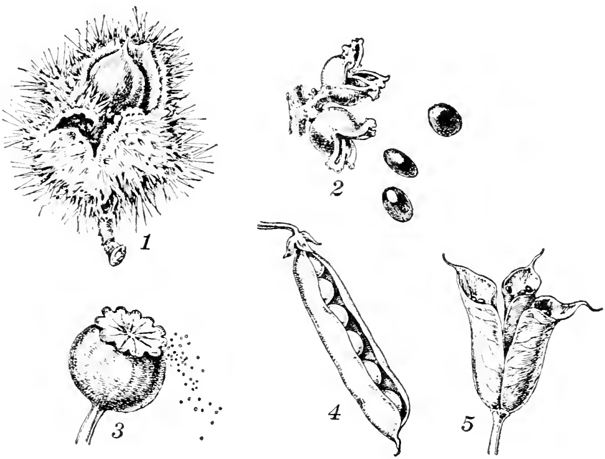


Fig. 197. Dehiscent fruit

Seeds are scattered by the opening of the fruit in a definite way. *1*, chestnut; *2*, witch hazel; *3*, poppy; *4*, pea; *5*, monkshood

twisting of the parts of the pod, as in the touch-me-not and the lupine (see Fig. 197).

Most plants depend upon outside agencies to scatter their seeds for them. The wind is active in the case of species whose seeds are either very small and light (the orchids) or supplied with expansions in the form of wings or tufts of hair that furnish a large area of contact with the air (see Fig. 196).

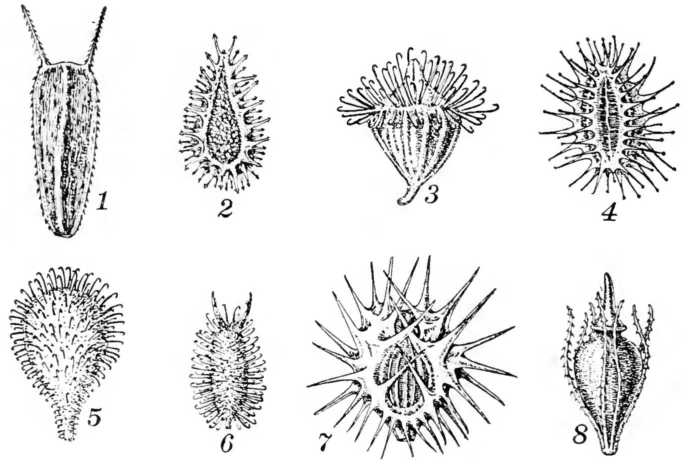


Fig. 198. Fruits scattered by passing animals

1, beggar-ticks, or bur marigold (*Bidens frondosa*); *2*, burdock (*Lappula echinata*); *3*, small-flowered agrimony (*Agrimonia parviflora*); *4*, carrot (*Daucus carota*); *5*, enchanter's nightshade (*Circaea lutetiana*); *6*, cocklebur (*Xanthium canadensis*); *7*, bur grass (*Cenchrus tribuloides*); *8*, spike rush (*Eleocharis ovata*). (*1*, *4*, *8*, enlarged; *2*, *6*, reduced)

Fruits that have hooks, as the cocklebur and beggar-ticks, attach themselves to the fur of passing animals and are carried considerable distances from the parent plant (see Fig. 198). Seeds that are inclosed in edible fruits are often distributed by animals, as they are swallowed and are then discharged from the intestines without having suffered any injury. Cherries, blackberries, and other small fruits are commonly distributed by blackbirds, robins, thrushes, and other birds (see Fig. 199).

From the point of view of the species there are three factors in seed dispersal that are of fundamental importance: (1) the number of seeds scattered; (2) the distance to which they are carried; and (3) the final lodgment in a place favorable both to germination and to later growth and development.

We can see that the more seeds there are scattered, the better are the chances that enough of them will find suitable lodgment to replace the individuals that die each year. On the other hand, an excessive number of seeds would be wasteful and might, under some circumstances, more than make up for the advantage of numbers. Thus, the orchids, which produce tremendous numbers of very small seeds, lose many; only a very small proportion of them ever develop into new plants. On the whole, the plants that depend upon the wind to scatter their seeds seem to maintain themselves and to invade new regions more successfully than those that depend upon other agencies for scattering the new individuals.

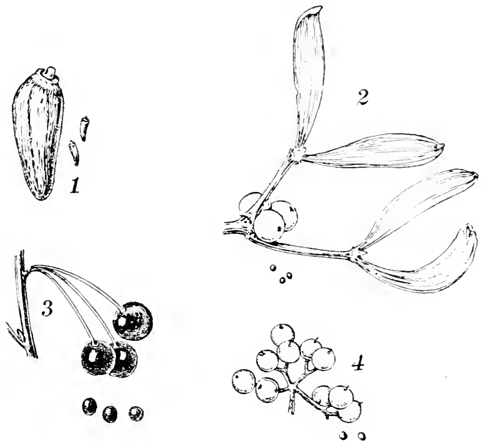


Fig. 199. Seeds scattered by birds

Birds eat the fruit and discharge the indigestible seeds. *1*, thistle; *2*, mistletoe; *3*, bird cherry; *4*, red-osier dogwood

Many plants have their seeds distributed by currents of water (streams of various sizes or ocean currents) or by wind currents acting on the water. Seed plants that grow in swamps or ponds are commonly dependent upon water currents for the dispersal of their seeds, but many seeds are also spoiled by the water.

MULTIPLICATION IN PLANTS

1. Cell division
   - In one-celled plants
     - Multiplication of individuals
   - In many-celled plants
     - Growth of tissues
     - Development
     - Repair of breaks etc.
     - Propagation
       - From root
       - From stem
       - From leaf
2. Grafting
   - Depends on cell division in cambium layers
   - Parts of graft
     - Stock
     - Scion
   - Kinds of graft
     - Twig
     - Bud
     - Bridge
   - Use of grafts
     - Multiply one variety of plant product at expense of another
3. Budding
   - In one-celled plants
   - In many-celled plants
     - Structure of bud
       - Stem
       - Leaves
       - Covering
     - Propagation by buds
       - Planting (potato)
       - Pollarding
       - Grafting
4. Reproduction
   - Asexual
     - Spores
   - Sexual
     - Gametes conjugating into zygote
       - Undifferentiated gametes
       - Differentiated gametes

Female		Male	
Larger	Resting	Smaller	Moving
Round	Receiving	Irregular	Supplying
(Smooth)		(Ciliated)	

5. Flowers as reproductive structures
   - Stamen (pollen-bearing organ)
     - Pollen, spore leading to formation of male gamete
   - Carpel (ovule-bearing organ)
     - Embryo sac, spore leading to formation of female gamete

Fertilization within ovule
Development of zygote within ovule
Supply of food for developing embryo from ovary parent
Supply of protective structures by ovary parent

6. Fruit in relation to reproduction
    - Origin
        - Ripened ovary + various adhering parts (calyx; receptacle; involucre)
    - Relation to seed
        - Protection
            - Spines
            - Hard shell
            - Taste disagreeable to animals
        - Escape and distribution
            - Dehiscence
            - Pores
            - Rot away or are eaten
            - Breeze-catchers
                - Wings; fluff etc.
7. Seed distribution
    - Factors related to preservation of species
        - Numbers
        - Wide dispersal
        - Finding of favorable lodgment
    - Means of distribution
        - By action of fruit
        - By moving animals
        - By wind
        - By water

QUESTIONS

1. What do you consider the lowest form of reproduction in plants? Why? What do you consider the highest form? Why?

2. What results from cell division in plants besides the formation of new individuals?

3. How does cell division as a means of reproduction differ from spore formation?

4. In what ways are a spore and a zygote alike? In what ways are they different?

5. How do the gametes of *Spirogyra* resemble the gametes of rock-weed? In what ways are they different?

6. In what ways are the gametes of rockweed like each other? In what ways are they different?

7. How does the relation between a flowering plant and its offspring differ from the relation between a rockweed and its offspring?

8. How can animals influence the distribution of plants? What animals in your region do?

9. What are the advantages of having seeds remain close to the base of the parent plant? What are the disadvantages?

10. What is there about the common weeds of your region that enables them to spread over a wide area?

11. What parts of the plant besides the ovary may be related to seed distribution?

12. In what ways can we control the multiplication of plants that are useful to us?

13. In what ways can we control the multiplication of plants that are harmful to us?

14. What different methods of plant propagation are used in your community for commercial purposes?

15. What use is made of cell division in one-celled plants?

16. How does the weeping willow extend its territory?

REFERENCE READINGS

DENSMORE, H. D. General Botany, pp. 154–159, Vegetative Reproduction.

WARD, C. H. Exploring Nature, pp. 75–78, "Scattering the Seed" (from Selina Gaye's "The World's Great Farm").

WATERS, H. J. Essentials of the New Agriculture, chap. xxxiii, The Fruit Crop.

Farmers' Bulletin 461, Grape Propagation.

Farmers' Bulletin 887, Raspberry Culture.

Farmers' Bulletin 1369, Bridge Grafting.

Farmers' Bulletin 1171, Growing Annual Flowering Plants.

Farmers' Bulletin 750, Roses for the Home.

Farmers' Bulletin 1311, Chrysanthemums for the Home.

Farmers' Bulletin 1370, Dahlias for the Home.

Farmers' Bulletin 1381, Herbaceous Perennials.

CHAPTER XLIII

MULTIPLICATION IN ANIMALS

Questions. 1. How do different kinds of animals multiply? 2. Do any species of animals multiply in more than one way? 3. Does every animal start as a single cell? 4. Do all animals take care of their young? 5. Are any animals able to take care of themselves the moment they are born?

351. Cell division. One-celled animals (protozoa), like one-celled plants, multiply by simple cell division; and many-celled animals, like many-celled plants, grow in size (1) by the increase in the number of cells through cell division, and (2) by the enlargement of the cells themselves through the assimilation of food. Again, as in plants, cell division in animals results in the healing of wounds and breaks, as when your hand is cut or when a bone is broken. This healing of skin or bone and other tissues is quite common among all kinds of plants and animals, and may be considered as a growth in response to stimulation set up by injury.

Not all kinds of tissues will produce new cells of the same kind. An injury to the brain will usually heal up by the formation of a scar of connective tissue. A wound on a tree often results in the formation of *callus* instead of growing wood and bark (cambium).

352. Regeneration. We saw that a portion of a plant is capable, under certain conditions, of regrowing the parts lacking to make a complete plant. A somewhat similar process is to be observed among certain animals. If the fore part of an earthworm is cut off, a new fore part is formed. If the hind end is removed, a new tail may be grown (Fig. 200). This process of regrowing a lost part is called **regeneration**, and is in some ways similar to the healing of a wound, since it depends on cell division; but it goes much farther.

When a lobster, a crab, or a crayfish has a claw or a leg caught or mutilated, it throws the limb off completely, the separation taking place along a definite plane between two of the joints, and then gradually grows a new appendage to take the place of the lost one. A single ray of a starfish will be regenerated, or even two or three rays (see Fig. 201). Salamanders regenerate tails and legs, and the triton, one of the lizards, can regenerate the eye. In general, however, the more highly specialized organs are not readily regenerated, and the highest animals do not regenerate lost parts as do the lower animals. A human finger when cut off will not be regenerated, although the stump will heal; and we should certainly not expect to get two whole pigs by cutting one into two parts.

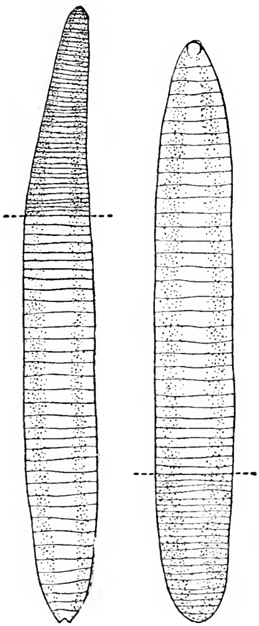


Fig. 200. Regeneration in earthworms

a, worm from which the anterior end had been cut off; *b*, worm from which the posterior end had been cut off. The dotted lines show where the cut was made. The shaded portions represent the new growths. (After Morgan)

Under certain conditions the tissues of one of the higher animals may begin to form masses of cells through cell division after full growth has been attained, and this leads to serious disturbances. The disease *cancer* is due to an abnormal growth whose causes are not understood.

353. Grafting in animals. Grafting is possible in animals, but in unequal degree among the various classes. In the insects experimental grafts have been produced by using two halves from two different individuals. From a practical point of view the most interesting are the grafts of skin from one person to another. In recent years many experiments have been made in grafting pieces of bone, sections of arteries, and even whole kidneys and other organs, from one animal to another. By experimenting upon dogs and other lower vertebrates with the same

care as would be used on human beings, surgeons are learning how to perform such operations safely. It has been supposed that it may some day be possible to replace a diseased kidney, for example, with one taken from a sheep or from another person who has recently died or who has had to have his kidney removed for some reason. This principle is now applied in the repairing of crushed bones. The injured part is neatly cut away and the missing portion is replaced with a suitable piece of the same size taken from one of the large bones that can spare it or from the leg of a sheep. The chief obstacle to the practical use of grafting on human beings and other warm-blooded animals lies in the fact that the protoplasm, especially of the white corpuscles, develops substances that are antagonistic to foreign proteins (see Chapter XXXIII).

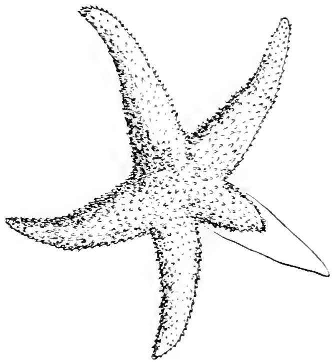


Fig. 201. Regeneration in starfish

The mutilation of starfish does not seem to kill them, for each part may regrow enough to complete a new individual. The regenerated ray shown in the figure is smaller than the rest, but in time the new ray would become full size, since regenerating tissues and organs grow faster than uninjured parts

354. Spores. A number of one-celled animals related to the ameba produce spores in a manner similar to that of plants. The number of spores is usually very large. In the malaria plasmodium spores are produced while the parasite is in the red corpuscles of the host. When the mass of protoplasm has grown to its limit, it breaks up into a large number of pieces, and these are thrown into the blood plasma. The chill takes place when the spores are being discharged.

355. Sexual reproduction among invertebrates. In all classes of animals reproduction may occur by the sexual method, although there are some species in which only asexual reproduction occurs. Among the invertebrates simple conjugation is found among the protozoa (see Fig. 202). Among the cœlenterates, sponges, starfish, clams, and oysters, fertilization usually takes place in the water, into which the male discharges

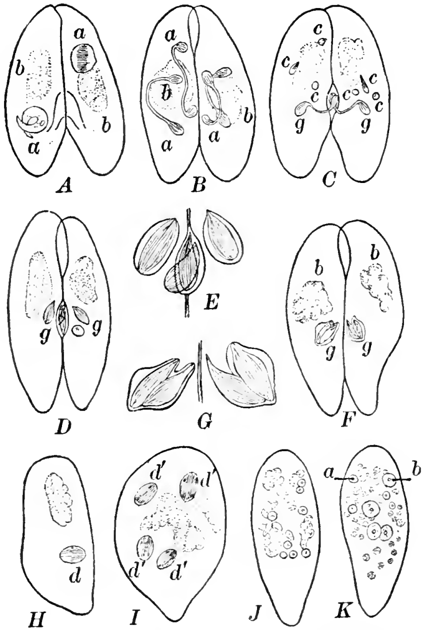


FIG. 202. Conjugation in *Paramecium*

There are two nuclei: *a*, the small one (*micronucleus*): and *b*, the large one (*macronucleus*). *A*: Two individuals become attached and their micronuclei begin to divide. *B*: The half nuclei divide a second time. Of the four units resulting, three are called polar bodies, *c*, and the fourth is a germ nucleus, *g*, which again divides. *C*: The germ nuclei are interchanged, one of each pair passing over to the opposite animal. *D*: Completion of interchange. *E*: Same, further enlarged. *F*: The active germ nucleus fuses with the stationary one. *G*: Same, enlarged. The macronucleus has broken up and disappeared. After the restoration of the micronucleus through fusion, *F*, the two individuals float apart. *H*: The new micronucleus, *d*, breaks up into two. *I*: Each portion splits again. *J*: A third division. *K*: Four of the nuclei become new macronuclei and four remain micronuclei. The rest of the protoplasm divides and four individuals result, each with micronucleus and macronucleus. (From Calkins, after Hertwig, and Maupas)

the sperm cells and the female the egg cells. Among certain invertebrates, however, the fertilized eggs are cared for in some way. Among crayfish and lobsters, for example, the eggs have a sticky surface and attach themselves to the abdominal legs of the mother and remain attached until they have hatched. Among clams the eggs remain inside the mantle cavity of the mother and so receive considerable protection until the embryos are able to swim away.

356. Reproduction in fishes. The female fish deposits the eggs in quiet places at the bottom of the sea, near shore, or in quiet pools of rivers. Then the male fish swims over the eggs, dropping out a quantity of *milt*, or *semen*, as the fluid containing sperm cells is called. These cells swim about in the water, and fertilization takes place very much as in the rockweed (Fig. 194).

A sperm cell of a fish is shown below in *4*, Fig. 203. When the nucleus of the egg has fused with the nucleus of the sperm, the combined nucleus begins to divide, and thus the development of a new fish is started.

The female gamete of the fish contains a small amount of food material in addition to the protoplasm. Upon this food the hatching fish lives until it has developed far enough to be able

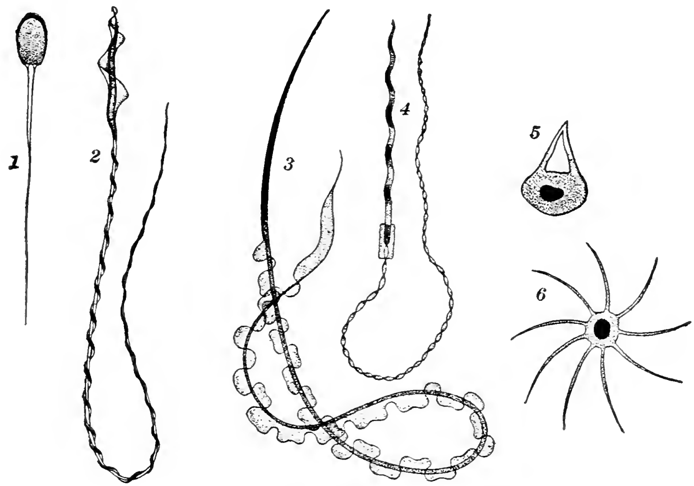


Fig. 203. Sperm cells of animals. (Very highly magnified)

1, pig; *2*, bird; *3*, salamander; *4*, ray; *5*, threadworm (*Ascaris*); *6*, lobster

to get its own food. In some species the adults swim about in the neighborhood of the developing fry and protect them from possible destruction by other fish. A few species, like the stickleback (Fig. 204), prepare a rather rough nest for the eggs. With most fishes, however, the sperms and eggs are thrown into the water by the adults and then left to themselves. Thus exposed, thousands of eggs are destroyed before they have a chance to develop into fish. Of course, thousands are also destroyed in the case of those species that protect their young, but it is likely that the proportion of loss is not so great among the latter.

357. Water essential to gametes. As we have seen, sexual reproduction means the union of two gametes. In addition to producing gametes, bringing them together is another problem of life. Moreover, the sperm and the egg cells (gametes) are unlike spore cells in that they are quite incapable of resisting

Fig. 204. The four-spined stickleback (*Apeltes quadracus*)

The adult fish swims about and through the nest, guarding the eggs while they are hatching

drought; drying kills them very quickly. A condition essential to reproduction is that the gametes be protected against drying up. Among organisms that live on land or in the air the older methods of bringing the gametes together can no longer serve. We have seen how this condition is met in the flowering plants. Among land animals there are special organs and modes of behavior that make fertilization possible.

358. Reproduction among batrachians. The frogs, which live on land and breathe air in the adult stage, go to the edges of pools and puddles at the breeding season. After the gametes are thrown into the water, where fertilization takes place, the adults pay no further attention to them. In some species of toads the fertilized eggs are kept in the mouth of the mother until the tadpoles are large enough to swim away. Several species of newts and salamanders show some care of the developing young, ranging all the way from abandoning them directly after discharge of the gametes to guarding within the body of the mother until the young are fully formed and able to shift for themselves.

Fig. 205. Finding a home for the young

Nest of a bluebird in natural hollow of a tree. (From photograph by L. W. Brownell)

359. Reproduction of insects. Among the insects, which of all the animals are most distinctly adapted to living in the air, the sperm cells of the male are passed directly into the body of the female through a special duct. The semen is discharged into a receptacle, from which the sperm cells pass, a few at a time, into another space in which the female gametes (eggs) are fertilized. A queen bee can retain a quantity of living sperm for two or three years, or even much longer, and can force the cells out of the receptacle from time to time as she produces new eggs. Even with the insects that normally lay their eggs in the water, as the mosquitoes, fertilization takes place within the body of the mother. There is a wide range of variation

between those that leave their eggs as soon as they are laid and those (like the wasps, bees, and ants) that build elaborate nests for them, store away food, and actually nurse and protect them.

360. Vertebrates. Among all the backboned animals above the amphibians fertilization takes place within the body of the mother. The eggs begin to develop immediately after fertilization and are retained for a longer or shorter period. Here they are not only protected from possible injury by enemies but are nourished, supplied with moisture, and in many cases kept warm. The eggs of reptiles and birds, as they leave the mother's body, are comparatively large, containing a considerable amount of concentrated food. Most reptiles and some birds leave their eggs to be hatched by the heat of the sun or at ordinary temperatures, but most of the common birds build more or less elaborate nests and care for the fledglings and for the eggs, besides supplying them with heat for hatching. The feeding of young birds by the parents is a very interesting thing to watch, and it shows a very complex development of instincts.

Among the mammals, the egg develops inside the body of the mother until it has acquired the general form characteristic of the species, and it is nourished by the parent for a long time after birth. Among the *marsupials*, or pouch animals, like the kangaroo and the opossum (see Fig. 60), the young are placed in an abdominal pouch immediately after birth; in the other mammals the young suckle from the milk glands of the mother. Passing from the lower mammals to the higher, the infancy of the individual becomes proportionately longer.

361. Infancy. If we compare the various groups of plants, or the various groups of animals, with respect to the amount of nourishment and protection or any other service that parents render to the young, we find that with the advance of life from the lowest forms to the highest there is an increase of dependence of the offspring upon the parent, and an increased advantage to the species.

The production of flowers and fruits and seeds, or the production of well-stored eggs, the building of nests, the carrying of the young, all these things mean a great expense to the organism in material and

energy: yet in any species of organism that produces these expensive structures or renders these expensive services *every individual gets the full benefit of the additional expenditure at the very beginning of his career.* We might say that an organism, apart from all other considerations, comes to be able to do all its life's work well just in proportion as its parents have guarded its youth and have given it a good start. In doing things for posterity an organism is thus merely repaying to the species what was done for it in the past.

MULTIPLICATION IN ANIMALS

1. Cell division
    - One-celled animals
        - Multiplication
    - Many-celled animals
        - Growth
        - Development
        - Healing and repair
        - Grafting
            - Possibilities within species
            - Possibilities from one species to another
            - Limitations
                - Of "taking"
                - Of staying
        - Regeneration
            - Possibilities
            - Limitations
        - Abnormal growths
            - Tumors; cancer
2. Spores in animals
    - Protozoa
3. Sexual reproduction
    - Conjugation
        - Protozoa
    - External fertilization
        - Among invertebrates (living in water)
        - Fishes
        - Some batrachians
    - Internal fertilization
        - Cartilaginous fishes
        - Some batrachians
        - Insects

Reptiles
  Hatching outside the body
Birds
  Hatching outside the body but with parent's heat
    Feeding after hatching
Mammals
  Hatching inside the body
    Feeding from mother's body after birth

4. Importance of prolonged infancy

QUESTIONS

1. What advantages have water animals over those that live on land or in the air? What disadvantages have they?

2. Of what advantage to a species is the production of very large numbers of spores or eggs? Of what disadvantage is it?

3. What are the advantages of asexual reproduction over sexual? What are the disadvantages?

4. What are the advantages that birds get from building nests for their young? What are the disadvantages?

5. What are the advantages of having the young able to take care of themselves early? What are the disadvantages?

6. What can be done to prevent the waste of millions of fish eggs?

7. How can we control the multiplication of useful animals?

8. How can we control the multiplication of harmful animals?

REFERENCE READINGS

Bureau of Fisheries. *Economic Circular 39*, Artificial Propagation of Carp.

Bureau of Fisheries. Annual Report, 1919, Appendix 2, Artificial Propagation of Salmons of the Pacific Coast.

Farmers' Bulletin 1040, Illustrated Poultry Primer.

Farmers' Bulletin 542, Organization of Poultry Clubs.

Robinson, J. H. Domestic Birds, pp. 16–23.

CHAPTER XLIV

IMPROVING QUALITIES IN PLANTS AND ANIMALS

Questions. **1.** What qualities in various plants are important in human affairs? **2.** What are the qualities in animals that are important to us? **3.** Are the domesticated plants and animals of today the same as those of ancient times? **4.** How do domesticated animals and plants differ from wild species? Where did they come from? **5.** How can plants be improved or otherwise changed? **6.** How can animals be improved or changed? **7.** Will large plants produce larger seeds than small ones of the same kind? **8.** Will large seeds produce larger plants than small ones of the same kind? **9.** Would more food change a pony into a full-sized horse?

362. No two alike. In some respects all the members of a species are alike. That is why we call all dogs "dog," and all apple trees "apple tree." But in some respects every individual is unique. If you should get the tips of your fingers inky and place them on a sheet of paper, you would make a set of marks that could not be *exactly* duplicated by anyone else. All species of plants and animals present this fact of **individual variation.** There is variation in size and in proportion (Fig. 206), in coloring and in shading, in the number of duplicated parts, like the ribs of a leaf or the hairs on a given surface (Fig. 207), and in physiological properties, like the yield of milk, the proportion of sugar, the amount of sleep people need, relative immunity to infection, and so on (Figs. 208 and 209).

363. Causes of variation. If a cow is undernourished, she will not yield as much milk as she might. This accounts for much of the difference between one farmer's cows and his neighbor's cows. On the other hand, in a herd of cows that receive the same care and feeding from birth, some will produce more milk than others. In the first case we say that the yield of the cow,

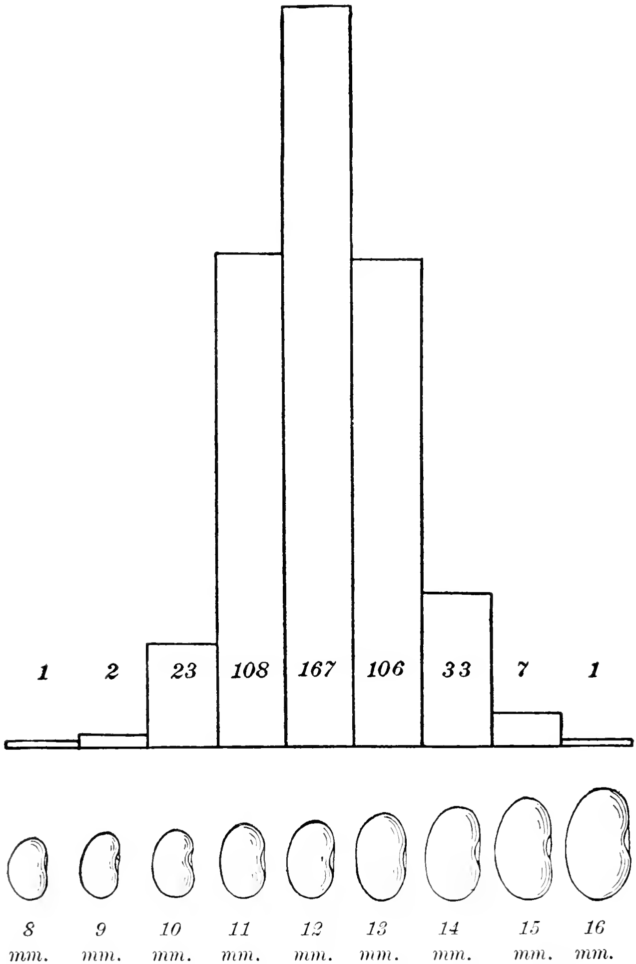


Fig. 206. Variation in size of similar units

On measuring the length of each of several hundred beans taken at random from a large lot, it was found that the largest was about twice as long as the smallest. The number of seeds of each size is shown by the relative height of the corresponding column above the horizontal line. Studies of this kind, repeated by many workers on many kinds of material, show not only that individuals vary, but that they *vary in a certain way*

influenced by her food, health, and care has been **modified**, whether favorably or unfavorably. In the second case we say that cows of different **breed** will yield different quantities and grades of milk, though all receive the same food and care. Differences in feeding affect plants as well as animals. In any season we may see fields of stunted, backward crops and fields of luxuriant growth. In every city we may see vigorous and alert men and women, as well as shriveled, miserable, and timid men and women. How far can these differences be controlled?

It is impossible to say offhand in any given case how much of the present condition of a plant or an animal is due to the qualities of its breed or strain and how much is due to the influence of its environment or experience; but every farmer knows that, besides *controlling the conditions* under which his plants and animals develop, he must also be careful to *select the right kind of stock or seed to begin with.* The best of care will not make the ordinary white bean seed develop into a plant bearing seeds as large as the lima bean, nor will extra feeding ever make a scrub cow give milk with the high proportion of fat that may be obtained from a good Jersey cow.

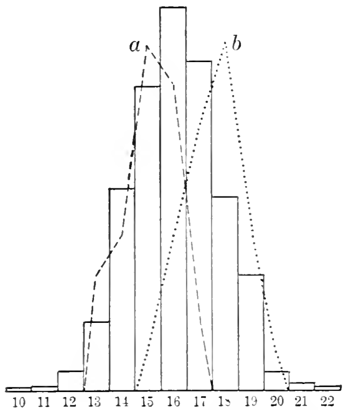


Fig. 207. Individual variation in the number of repeated parts

The principal veins on each side of the midrib on a beech leaf vary from 10 to 22. The number most frequently found is 16. The vertical columns correspond in height to the frequencies with which the various numbers of veins occur. Broken line *a*, a tree in which the number of veins varied from 13 to 17, leaves with 15 veins being most frequent. Dotted line *b*, another tree, in which the veins varied from 15 to 20, 18 veins being most frequent. Each tree has its individuality, and each leaf has its individuality

There are, therefore, three lines of control: (1) Since there are so many varieties of each species, we must select the best strains of each kind. (2) Having the plants and animals that

we have, we must give them the most favorable conditions for growth and development. (3) We must try to find out how the breeds or strains themselves can be improved.

364. Improvement by selection. For centuries the people who raise plants and animals have carefully watched their crops or flocks to find the most desirable individuals to be the parents of the succeeding crops or flocks. The best heads of wheat are selected to serve as seed for the next year; the best beans and the best potatoes are set aside as the progenitors of the crops to come; the best milk cows are selected to be the mothers of calves; the swiftest mares are the mothers of colts; and so on. In this way there has been a steady improvement in the stock of domestic plants and animals (Figs. 210, 211). The plants cultivated in the nineteenth century were better plants, from the farmer's point of view, than those cultivated in the tenth century; and so with the animals cultivated at different times.

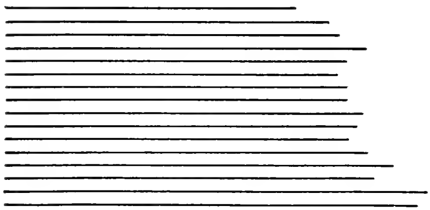


Fig. 208. Variation in physiological characteristics

Each line represents the relative amount of milk given by 16 cows in one month. The poorest yield (represented by the shortest line) averaged 20 pounds a day; the best cow averaged 30 pounds a day. Not only did one cow differ from another, but for each cow the yield varied from day to day. In like manner, the percentage of fat in the milk varied from cow to cow; and for every cow, from day to day

Careful observers familiar with farm life and practice have noted that cultivated races of plants and animals tend to deteriorate, or decline in quality, in a few generations *unless the selection is continued every year.* The explanation of this was not known. The only remedy is to select for every generation the best or the most desirable individuals or seeds.

There has been improvement, then, through artificial selection, but it has not insured the permanence of certain qualities. Selection must be continuous.

365. Making the most of our plants. Having selected the best seeds or the best types, the next problem is to make the most of each crop. We know that plants are influenced by the physical conditions in which they live, so that we are able, to a certain extent, to control their behavior.

1. *Soil.* The soil must have a texture that will permit both air and water to penetrate to the roots, and at the same time the surface must not allow the water from below to evaporate too rapidly. To insure the right physical condition the soil is cultivated—plowed to bring up the deeper layers and to break up the packed earth, and harrowed to crumble the lumps further into loose particles. If there is too much clay, sand has to be added; if it is too sour, lime has to be added; and, in general, fertilizer of one kind or another is mixed into the earth to supply ingredients needed for the particular crop or to supply deficiencies in the particular soil. Since some plants depend upon the coöperation of particular species of bacteria in making use of atmospheric nitrogen, modern farm practice has often added cultures of such bacteria to the prepared soil.

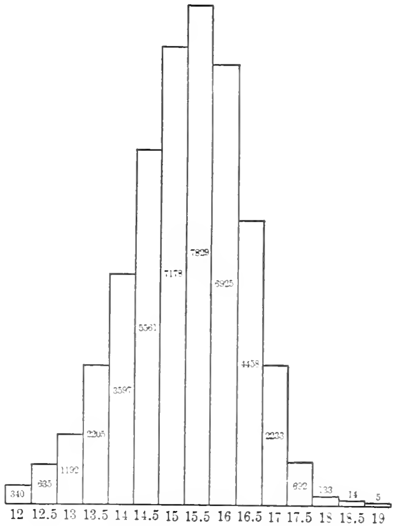


Fig. 209. Variation in physiological properties

Forty thousand sugar beets, tested individually, showed from 12 per cent to 19 per cent of sugar. Beets containing 15.5 per cent of sugar were the most frequent, but there were almost as many beets with 15 per cent or with 16 per cent. As the percentage of sugar departs more from the typical 15.5 per cent, the number of individuals with a given sugar content diminishes, so that the extremely poor and the extremely rich beets are also fewest in number

we have, we must give them the most favorable conditions for growth and development. (3) We must try to find out how the breeds or strains themselves can be improved.

364. Improvement by selection. For centuries the people who raise plants and animals have carefully watched their crops or flocks to find the most desirable individuals to be the parents of the succeeding crops or flocks. The best heads of wheat are selected to serve as seed for the next year; the best beans and the best potatoes are set aside as the progenitors of the crops to come; the best milk cows are selected to be the mothers of calves; the swiftest mares are the mothers of colts; and so on. In this way there has been a steady improvement in the stock of domestic plants and animals (Figs. 210, 211). The plants cultivated in the nineteenth century were better plants, from the farmer's point of view, than those cultivated in the tenth century; and so with the animals cultivated at different times.

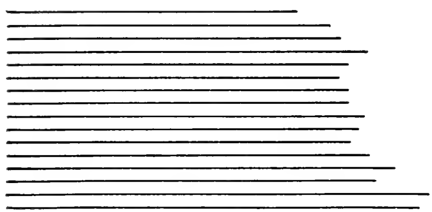


Fig. 208. Variation in physiological characteristics

Each line represents the relative amount of milk given by 16 cows in one month. The poorest yield (represented by the shortest line) averaged 20 pounds a day; the best cow averaged 30 pounds a day. Not only did one cow differ from another, but for each cow the yield varied from day to day. In like manner, the percentage of fat in the milk varied from cow to cow; and for every cow, from day to day

Careful observers familiar with farm life and practice have noted that cultivated races of plants and animals tend to deteriorate, or decline in quality, in a few generations *unless the selection is continued every year.* The explanation of this was not known. The only remedy is to select for every generation the best or the most desirable individuals or seeds.

There has been improvement, then, through artificial selection, but it has not insured the permanence of certain qualities. Selection must be continuous.

365. Making the most of our plants. Having selected the best seeds or the best types, the next problem is to make the most of each crop. We know that plants are influenced by the physical conditions in which they live, so that we are able, to a certain extent, to control their behavior.

1. *Soil.* The soil must have a texture that will permit both air and water to penetrate to the roots, and at the same time the surface must not allow the water from below to evaporate too rapidly. To insure the right physical condition the soil is cultivated—plowed to bring up the deeper layers and to break up the packed earth, and harrowed to crumble the lumps further into loose particles. If there is too much clay, sand has to be added; if it is too sour, lime has to be added; and, in general, fertilizer of one kind or another is mixed into the earth to supply ingredients needed for the particular crop or to supply deficiencies in the particular soil. Since some plants depend upon the coöperation of particular species of bacteria in making use of atmospheric nitrogen, modern farm practice has often added cultures of such bacteria to the prepared soil.

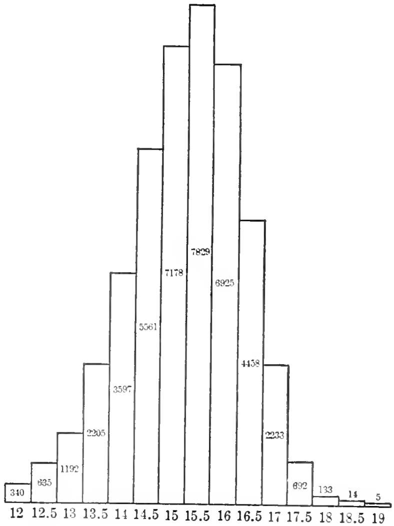


Fig. 209. Variation in physiological properties

Forty thousand sugar beets, tested individually, showed from 12 per cent to 19 per cent of sugar. Beets containing 15.5 per cent of sugar were the most frequent, but there were almost as many beets with 15 per cent or with 16 per cent. As the percentage of sugar departs more from the typical 15.5 per cent, the number of individuals with a given sugar content diminishes, so that the extremely poor and the extremely rich beets are also fewest in number

2. *Water.* Where conditions are otherwise quite favorable, the quantity of water may determine the size or character of the crop. In most farming we have no control whatever over the supply of water, but the farmer can do a great deal to make better use of the water he gets. For example, by planting his seeds properly and packing the soil down just right he can hasten the absorption of water by the seeds and thus hasten

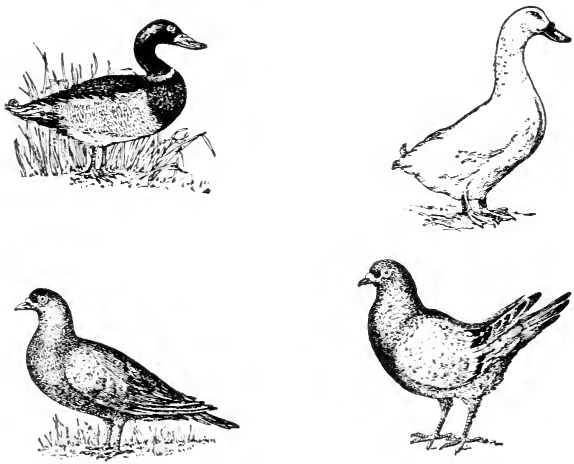


Fig. 210. Improved varieties of domestic birds

their sprouting; or in hoeing he can heap the soil about the bases of the plants so as to prevent too rapid evaporation and get fuller use of the moisture. Where irrigation is used the water is supplied to the fields or orchards in measured quantities, so that fairly uniform conditions of growth can be assured.

3. *Management.* Each kind of crop must be planted early to get as long a growing season as possible, or as early a market, or some other advantage. On the other hand, there is danger in planting *too early*; control depends upon knowing *all* the important facts. If the seeds are too near the surface, the seedlings may dry up before they are well started; if they are too deep, the young plant uses up too much of its food reserve in reaching

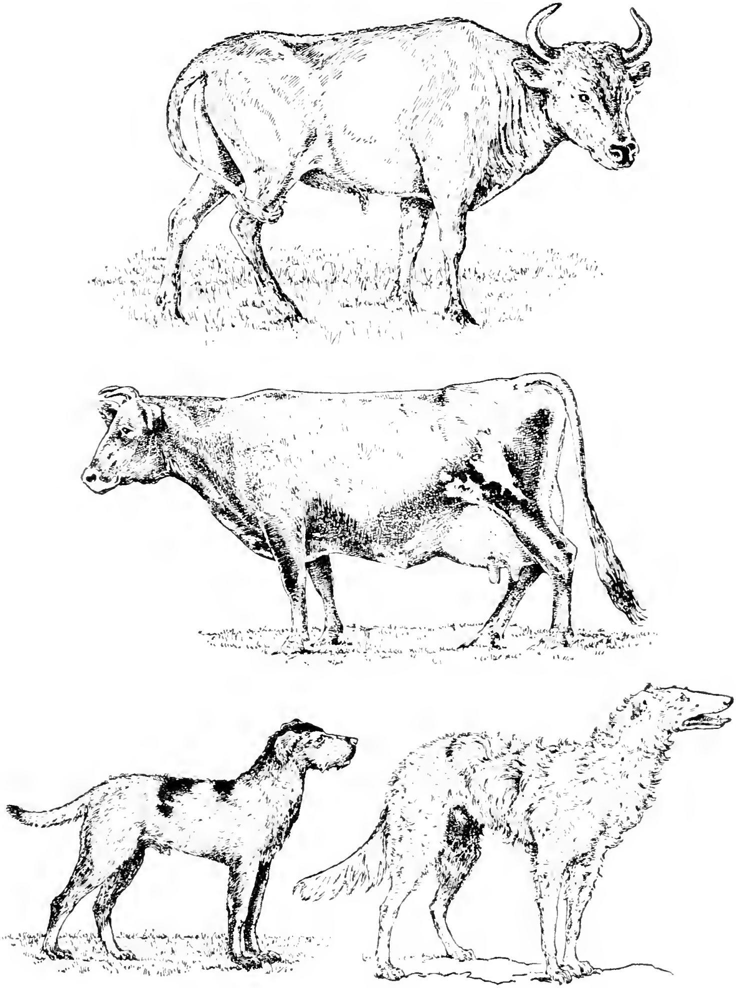


Fig. 211. Improved varieties of domestic animals

The contrast between the modern high-bred Jersey and the ancient banting, or between the high-bred Russian wolfhound and an ordinary yellow dog, is typical of the changes brought about in the course of many generations by the steady work of selecting the most desirable kinds of individuals to be the parents of the following generations

the surface and may be seriously delayed. If the plants are too far apart, there will be more work per thousand plants or less yield per acre; if they are too close together, they will crowd each other. By means of rotation of crops the nitrogen removed by some crops is restored by the nitrogen-fixing bacteria that coöperate with the plants of the bean family. Then there is the weeding, which must be done in a way that will produce the most favorable results for the crop.

4. *Protection.* Cultivated plants, in order to yield both the best quality and the largest quantity, must be protected from their many dangers and enemies. The temperature has to be considered, as in deciding upon the best time for planting. Sometimes it is necessary to have seedlings ready to set out when the frost is gone; sometimes it is necessary to shield plants from excessive sunshine; and often the wind is a serious factor, especially in grain-raising and fruit-raising. The most serious problem in crop-raising of all kinds is the blighting effect of various plants and animals—chiefly various species of fungi and of insects (see Chapter XLIX). The protection consists of a great variety of measures: the selection of seeds and tubers that are free from infection; the sterilizing of seeds and tubers; the use of powders and sprays on the growing plants. For each particular kind of crop and for each particular kind of enemy a definite procedure must be worked out. The many stunted, blotchy, speckled, or twisted potatoes and other vegetables and fruits that come to market give only a slight suggestion of the great extent to which our useful cultivated plants are injured by these enemies.

5. *Making the most of our animals.* The management of animals, like the management of plants, depends upon an increasing knowledge of the factors that make for their healthy growth and development, and that protect them from dangers and disease. There is of course the question of suitable food—suitable in quality and in proportions, or *balance*, as well as in total quantity; and it must meet the needs of different ages. If a calf has been underfed, he will have a comparatively large head,

long legs, and large joints. No amount of feeding later in life will make up for poor development. For this reason a mother who is nursing needs more lime than she does at other times; and the same is true of a milk-producing cow. The hen that is to lay eggs must also have a different diet from a hen that is merely to remain alive or get fat. Other factors that influence human life are important in maintaining the health of our stock —temperature, exercise, exposure to wet or chilling, exposure to infection, and injury by parasites. It is because the care bestowed upon animals does make a difference that it is important to know the biology of domestic animals.

6. *Getting better types of organisms.* From time to time there is introduced from a foreign country a variety of plant or animal that is superior in some respects to any previously cultivated in a given region. In this way the cultivators become acquainted with better varieties of wheat, melons, beans, and strawberries or sheep, swine, cows, and chickens. A transported variety sometimes does better than the native because in the new surroundings it does not have to contend with its usual enemies. The agents of the Department of Agriculture are constantly exploring the markets and foreign countries for plants and animals that would suit special conditions in the various parts of our country.

From time to time there appears a freak plant or animal among those in cultivation. Thus, there appeared among a flock of sheep on a Massachusetts farm a male with very short legs and very long trunk (see Fig. 212). This freak was not particularly handsome, but when it had grown up the owner concluded that this odd shape was of value, since it prevented the animal from jumping fences. By using this as one of the parents for another flock he obtained in the course of years an increasing number of these short-legged sheep. At other times there have appeared sheep with unusually long wool, and these were saved as a basis for further breeding; or sheep without horns arise suddenly in a flock. These sports, as the breeders call them, or jumps, also occur in plants. A wild dewberry without thorns was the basis

for Luther Burbank's thornless blackberry. A grain stalk may appear without the sharp bristles among the grains (see Fig. 213). A seedless plum or a seedless orange grows unexpectedly upon a tree that had previously borne only respectable fruit with seeds. These sudden departures from parental types of plants or animals are called **mutations**. They differ from mutilations,

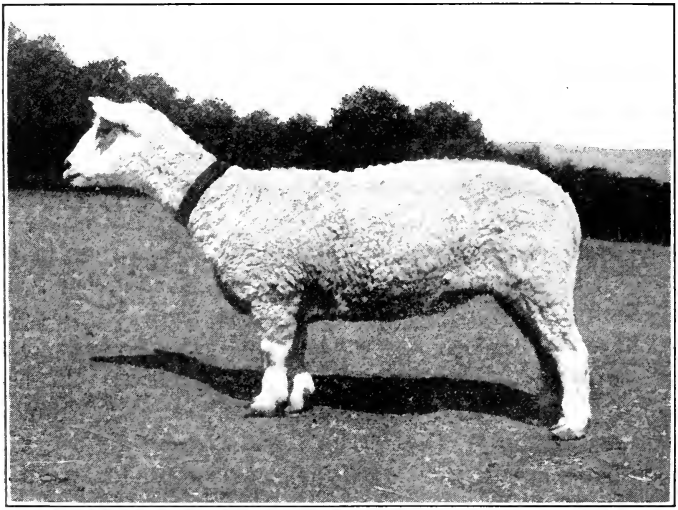


Fig. 212. The Ancon type of sheep

There are no known descendants of the famous Ancon ram that appeared in Massachusetts in 1791. The animal shown in the picture has the short legs and long body of that sport, but it was born from apparently normal parents on a Norway farm in 1919, and was found by Nils Thorshaug, the live-stock officer. One of her daughters is of the same type; the other descendants are normal. (Photograph by Director Bæröe of the Jönsberg Agricultural School, Norway). (Courtesy of Dr. Christian Wriedt)

or from the effects of overfeeding or other conditions in the surroundings, in *breeding true*, that is, in giving rise to offspring like themselves. Where mutations have desirable qualities, they are preserved for further breeding.

In modern times the breeders of plants and animals have not been content with finding desirable plants and animals by chance, with having them introduced occasionally from abroad,

or with waiting for the very rare sport; they have attempted to bring about variations of a kind that were both useful and permanent. But it is only since the beginning of the present century that the biological principles necessary for controlling plants and animals in this way have been known. These biological principles have to do with **heredity**, or that relation between parents and offspring which concerns their resemblances and differences. Working on these principles, the breeders of plants and animals are systematically improving domestic organisms in a way that would have been considered little short of magic only thirty years ago.

IMPROVING QUALITIES IN PLANTS AND ANIMALS

1. Variation in plants and animals
    - How plants and animals differ within a species
        - Size
        - Number of repeated parts (ribs on leaf; florets on head; stamens; segments in worm; hairs; spines; markings)
        - Dimensions of repeated part (hair; cotton fibers; horns; leaves; seeds; eggs; fingers; vocal cords)
        - Physiological properties
            - Pigmentation
            - Proportion of sugar; fat; protein; alkaloid
            - Muscular capacity
            - Speed of reaction
            - Amount of milk; amount of nicotin
            - Resistance to particular poison
            - Susceptibility to particular infection
            - Educability in general; special
    - Sources of variation
        - External conditions (resulting in modifications)
            - Food and air
            - Moisture
            - Temperature
            - Chemical (poisons, parasites, etc.)
            - Fatigue
        - Internal conditions (derived from ancestry)
        - (Mutations)

2. Control of plant and animal qualities
    - Qualities that are important for human affairs
    - Management of domesticated or cultivated organisms
        - Plants
            - Soil
                - Conditioning
                - Fertilization
                - Cultivating
                - Surface covering
            - Water
                - Mulch
                - Hoeing
                - Irrigation
                - Dry farming
            - Planting
            - Rotation
                - For soil preservation
                - For avoiding parasites
            - Protection
                - Adverse conditions
                - Enemies
                    - Fungi
                    - Insects
        - Animals
            - Feeding; protection
    - Selection
        - Examples
            - Best seeds
            - Sweetest beets
            - Hardiest wheat
            - Brightest flowers
            - Fastest horses
            - Longest cotton
            - Finest wool
            - Yellowest corn grains
            - Longest-legged hounds
            - Shortest-legged sheep
            - Rust-resisting wheat
            - Cows with most milk
            - Cows with most fat in milk
            - Cattle immune to Texas fever
        - Need for constant selection
            - To avoid deterioration; for possible improvement
3. Sources of types for selection
    - Mutations, or sports
    - Importation of new forms
    - Artificial stimulation to variation
        - Changed conditions
        - (Hybridization, which rests on understanding of heredity)

QUESTIONS

1. In what ways do the members of your class resemble one another?

2. In what ways do the members of your class differ?

3. How can you measure the differences or resemblances among individuals?

4. What differences are there in a given lot of seeds (or leaves, insect wings, thumbs, flowers, or other natural objects) of the same kind?

5. What is the advantage to man of cultivating or domesticating animals instead of using wild ones? What is the disadvantage?

6. What are the advantages of cultivating or domesticating plants instead of using wild ones? What are the disadvantages?

7. What are the advantages that some breeds of domesticated animals raised in your region have over some other breeds? What are the disadvantages?

8. What are some of the advantages that some of the breeds of domesticated plants raised in your region have over other breeds? What are the disadvantages?

9. What is there in your region to show that some ways of managing plants are more productive than other ways?

10. What is there to show that some kinds of management in plant-raising result in better qualities?

11. What is there in your region to show that some ways of managing animals are more productive than other ways?

12. What is there to show that differences in management bring about differences in the quality of domestic animals?

13. How can you tell whether the differences observed between two individuals of the same kind are due to differences in ancestry or breed, or to differences in the conditions under which they developed?

14. What would be the use of knowing how various kinds of differences are produced?

15. What modern plants or animals were not cultivated in ancient times?

16. What domestic plants or animals are being replaced by new sources of supply or made unnecessary by new ways of living?

17. What plants or animals that were formerly cultivated are no longer of great importance?

18. Look over the classification of plants and that of animals (Chap. VII) and list those groups from which we have cultivated or domestic representatives.

REFERENCE READINGS

(See reading lists on pages 518 and 531)

CHAPTER XLV

PLANT BREEDING

Questions. 1. How can plants be made to vary? 2. Will plants that have better growing conditions produce better offspring? 3. Can plants of two different species produce offspring if the pollen is crossed? 4. Why do plants resemble their parents? 5. Why do plants differ from their parents? 6. How are new breeds of plants produced?

366. Inducing variations. Improvements in domestic plants (as well as in animals) have come from preserving and multiplying those individuals that showed some superiority over their fellows. For a long time, therefore, people have tried to find ways of bringing about *variations* in plants. It was expected that, while some of the variations might be useless or even undesirable, some at least would tend to be useful. How can variations be brought about? Certainly we know that plants supplied with favorable conditions from the time the seed germinates will thrive better than those not so favored; well-conditioned corn will produce larger seeds, well-conditioned potato plants will produce larger tubers, and so on. Taking good care of organisms is thus the first step in their cultivation. But sometimes a change in one condition or factor brings about a marked difference in results. Raising wheat in a colder region might shorten the time between planting and ripening. More iron in the soil might change the color of the blossoms. Shading the plants might result in larger, thinner leaves. By giving their plants the most favorable conditions for development, and by changing one or another condition, cultivators have attempted to increase the chances of finding desirable variations.

Another source of variation was found in **hybridizing**. This is the procedure of crossing two strains of organisms. For example, the pollen from one variety of orange is placed on the stigma

of another variety (that has not yet been pollenated) and the stigma is then protected from further pollenation. The resulting seeds are planted, and the new generation is expected to be different in some ways from each of the parents. Any desirable individuals that appear in this generation are kept for further cultivation. This principle has been applied very extensively in the attempt to find new and useful variations, among animals as well as among plants (see Fig. 213). Many of the most valuable domesticated organisms have originated through hybridization.

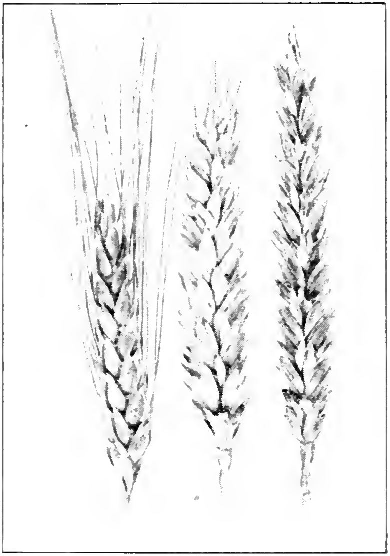


Fig. 213. Wheat varieties and their hybrid

At left, head of "bearded" wheat; at right, head of "beardless" wheat; in middle, head of wheat resulting from a cross of the other two types, grown at the Minnesota Agricultural Experiment Station. (From Bergen and Caldwell's "Practical Botany")

367. Instability of fluctuations. Plants normally differ from each other, even if they are grown from seeds in the same fruit. They also differ from each other if they are grown under identical conditions. The differences which result from modification by conditions or environment are called *fluctuating variations*, or **fluctuations**, since they flow up and down as conditions change to more favorable or less favorable. Now if we find a few individuals in a plot that are superior to others because they happen to have had somewhat better conditions—moisture, soil materials, protection from parasites or disease—we properly select them for the next crop seed. But will the next crop be as much better than this year's as our seed plants were

better than their fellows? Will the seeds of the tallest plants always yield a new generation of the same qualities? Experience has shown that we cannot depend upon their doing so *unless the superior conditions are also repeated.* If the conditions for the next generation are only average or inferior, the good seed will not insure a superior growth. If we select variations from the average which depend upon favorable conditions, we have to continue selection, generation after generation.

368. Instability of hybrids. By crossing two varieties of plums or apples or potatoes or cabbages or squashes we can often get a crop of individuals (hybrids) that differ from either parent in a striking way; but if we plant the seeds of one of these improved or interesting hybrids, the following generation will show an even greater assortment of unusual individuals than we had among the hybrids or else will show an assortment that is more like the grandparents. It has been known among breeders of plants (as well as of animals) that the descendants of hybrids tend either to "break up" or to "throw back" to the ancestral forms. For this reason it is not possible to rely upon hybrid seed, for there is no telling what it will develop into. If you had a hybrid apple that combined the keeping qualities of one brand of winter apple with the large size or fine flavor of another variety, you would want to multiply this new type; but if you depended upon the seeds, you would be disappointed.

369. Preserving hybrids. If you knew which tree produced the new kind of apple, you could multiply the number of branches bearing such hybrids without using the seeds at all. By grafting twigs of this tree upon the stocks of other vigorous apple trees you could in a few years transform an orchard bearing an old type of apple into one bearing the new type, without ever using any seeds. This *vegetative propagation* not only insures a greater degree of uniformity in the product but also saves much time, since fruit can thus be obtained without waiting for plants to grow from seeds until they are old enough to bear.

The same principle applies to raising improved potatoes, for example, except that here we use, not grafting, but bud-

sprouting from the eyes of the new kinds of tubers. In raising seedless varieties of fruit, *vegetative propagation* is the only possible procedure. The breeder may use grafting for trees, and cuttings, tubers, bulbs, or layering for smaller plants. For many of the common crop plants, such as grains, the bean family, radishes, the cucumber family, and others, the preservation of hybrids through vegetative multiplication is impossible because these plants are annuals and have no parts from which new individuals can grow except the seeds. New varieties that arise from hybridizing are thus likely to get lost.

370. Heredity. How is it that the characters of organisms are so regularly repeated in their offspring? And how is it that in spite of the close resemblance between parents and offspring these are never exactly alike in every point? All the speculation on these questions led to nothing until some experiments were undertaken. The results of some of these experiments have helped to solve in part the practical problem of keeping desirable variations that result from hybridizing. The first systematic experiments of which we have any record were those of Gregor Mendel (1822–1884), an Austrian monk. Mendel had long puzzled his mind over the great amount of variation among his garden peas. There were tall plants and short ones, plants with white flowers and plants with colored flowers, with yellow seeds and with green seeds, with smooth seeds and with wrinkled seeds. All in all he studied seven different pairs of contrasting characters in the pea plants. He noticed further that a given plant might have any *combination* of single members of these seven pairs. Thus, a hairy plant might be tall or it might be short; a tall hairy plant might have white flowers or pink flowers; it might have yellow seeds or green seeds; and so on.

371. Mendel's experiments. Fixing his thought on *a single character at a time* instead of trying to think of the variety as a whole, Mendel crossed garden-pea plants that differed from each other. He crossed green-seeded with yellow-seeded, tall ones with short ones, hairy ones with bald ones, and so on for his seven pairs of characters. Moreover, in all his experiments he

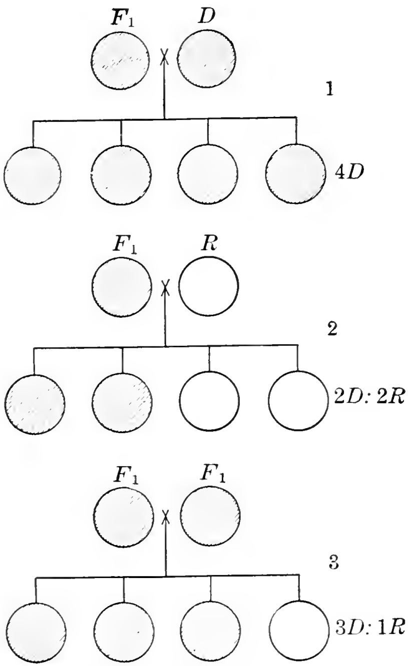


Fig. 214. Mendel's law of segregation

When two individuals with a pair of alternative characters are mated, the offspring will all have the character of one of the parents; this character is called the *dominant* one, and the alternative character is called the *recessive*. The hybrid offspring of such a mating is represented in the diagram by F_1. Offspring of this kind *resemble* the dominant parent, D, but experiments show that there is a real difference. If such a hybrid is mated with one of the pure dominant type, *1*, the next generation will all *appear* dominant. If such a hybrid is mated with an individual of the recessive type, *2*, the offspring will consist of dominants and recessives, in about equal numbers. If two such hybrids are mated, *3*, the offspring will show both dominants and recessives, in the proportion of three to one. This splitting up of the offspring of hybrids into two types showing ancestral factors is almost universal; it is called *segregation*

with green seeds (see table on opposite page); that is, the two original parental types reappear. There is segregation in the proportion of three dominants to one recessive (3:1). By inbreeding a second time we find further segregation (column marked "Third Hybrid Generation"). But here a new fact appears: some of these plants in the second hybrid generation *breed true*—some of the yellows (dominant) and *all of the greens* (recessive). The greens are found to breed true in every succeeding generation, in spite of the fact that they were derived from yellow hybrids. Plants (or animals) that behave in this manner are called **extracted recessives.** Regardless of the fact that they have descended from yellow (dominant) plants (first hybrid generation), such recessives are considered pure because *they always do breed true.* Again, those

RESULTS OF INBREEDING HYBRIDS FROM YELLOW-SEEDED AND GREEN-SEEDED GARDEN PEAS[1]

Parent Generation	First Hybrid Generation	Second Hybrid Generation	Third Hybrid Generation	Fourth Hybrid Generation
		Yellow	YELLOW	YELLOW
			Yellow	YELLOW
				Yellow
	Yellow	Yellow	Yellow	Yellow
		Yellow	Yellow	Yellow
				Green
			Green	GREEN
		Green	GREEN	GREEN
		Yellow	YELLOW	YELLOW
			Yellow	YELLOW
		Yellow		Yellow
	Yellow		Yellow	Yellow
		Yellow	Yellow	Yellow
				Green
			Green	GREEN
YELLOW × GREEN		Green	GREEN	GREEN
		Yellow	YELLOW	YELLOW
			Yellow	YELLOW
		Yellow		Yellow
	Yellow		Yellow	Yellow
		Yellow	Yellow	Yellow
				Green
			Green	GREEN
		Green	GREEN	GREEN
		Yellow	YELLOW	YELLOW
			Yellow	YELLOW
				Yellow
	Yellow	Yellow	Yellow	Yellow
		Yellow	Yellow	Yellow
				Green
			Green	GREEN
		Green	GREEN	GREEN

[1] Four individuals are shown for each generation, simply to give the *proportions* of each type produced.

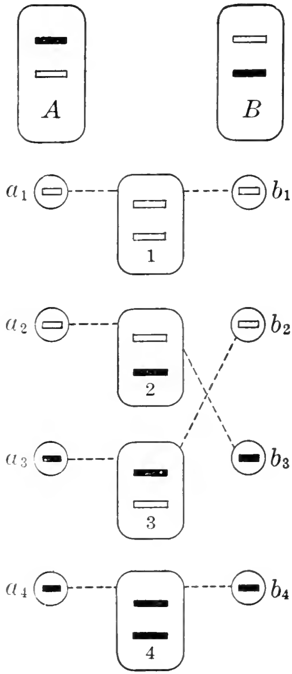


Fig. 215. The law of segregation

A hybrid produces germ cells of two kinds with respect to a pair of contrasting characters — one kind bearing the elements needed for developing the dominant character, and the other kind bearing the elements that result in the recessive. If two individuals, *A* and *B*, both hybrid and both showing the dominant character, are mated, they may give rise to three kinds of offspring. The germ cells given off by *A* are of two kinds, a_3 and a_4 having the factor for dominance, while a_1 and a_2 bear the factor for recessiveness. In the same way, *B* bears two kinds of germ cells. The two kinds of eggs can combine with the two kinds of sperms in four ways: (1) a recessive egg combines with a recessive sperm; (2) a recessive egg combines with a dominant sperm; (3) a dominant egg combines with a recessive sperm; (4) a dominant egg combines with a dominant sperm. As a result, half the offspring are again hybrid and the other half pure; and the pure are likely to be dominants and recessives in equal numbers. Note that the hybrids resemble the dominant grandparent, giving the *appearance* of one recessive to three dominants

yellows which upon self-pollenation yield yellow-seeded plants that bear yellow-seeded offspring are also pure. These lines are shown in the table by being printed in capital letters. In each generation, then, some of the apparently dominant plants will behave like hybrids and split up again when they reproduce; one out of every three dominants will turn out to be a pure dominant; and the recessives will remain pure, or capable of reproducing their characters.

An attempt to explain how this segregation is brought about during reproduction is illustrated in Fig. 215. This explanation was not known to Mendel but has been worked out since his time by careful experiments with plants and animals and by studies of the changes which take place in the cells at the time the germ cells (gametes) are formed, at the time of fertilization, and in later development.

374. Combinations of characters. In the meantime we must not forget that *every organism is made up of many characters.* After showing

that his garden peas, on crossing, manifested dominance and subsequent segregation for each pair of characters, Mendel went farther and experimented on the results of crossing plants *with different combinations of characters.* Two plants, for example, differ not only as to the color of the seed but also as to tallness. What happens when they are crossed? Experiments showed that when a tall green-seeded parent is crossed with a short yellow-seeded one, the next generation appeared to be all tall yellow. The hybrids resembled one parent altogether in one character, and the other parent entirely in the other character (see Fig. 216). In the following generation the offspring of such hybrids would appear in four types: tall yellow, short yellow, tall green, short green.

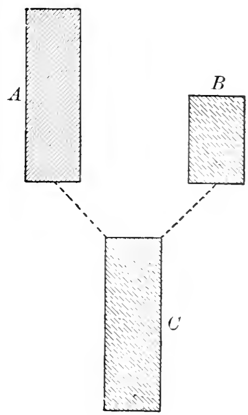


Fig. 216. Inheritance of two or more characters

The offspring of two parents, A and B, resembles both parents, but it does not, as a rule, stand midway between the parents with respect to the several characters. Instead, the offspring will be like one parent in some characters and like the other parent in other characters

Experiments of this kind have since been repeated by the thousand. From them we conclude that each pair of alternative characters behaves according to the first two laws (dominance and segregation), regardless of the other characters present. This general fact is called the **law of unit characters**. This law helps us to understand how there can be such diversity among the individuals of any species of plants or animals. The greater the number of characters that make up a species, the greater is the possible number of *combinations*, and the smaller is the chance that any given combination will occur again.

These three laws of heredity—*dominance, segregation, and unit characters*—are known as Mendel's laws or principles, because they were first discovered by Gregor Mendel. Unfortunately Mendel did not publish his results, and his researches

were practically lost to the world for fifty years. At the beginning of the twentieth century several other scientists, working independently, discovered the same principles, and later the records of Mendel's experiments were found. These principles serve as a basis for practical work of great value in the breeding of plants and animals.

375. Applied Mendelism. The region about Pullman, Washington, is one of the best wheat-growing countries in the world. Here the farmers had for years tried out many varieties of wheat in order to decide which was the most profitable to grow. They found only the Little Club variety at all satisfactory, but that also had its faults. The straw was strong enough to withstand the summer storms and the head remained closed after the grain was ripe, thus preventing loss before harvesting; but when planted in the fall it would be frozen during severe winters —once every three or four years. Although the farmers could get better crops by planting in the fall, they could not afford to lose every third or fourth planting. The problem was, therefore, to combine the good stem and head qualities of Little Club with the frost-resisting qualities of some other variety.

Mr. W. J. Spillman, at that time agriculturist of the experiment station at Pullman, began a series of experiments in crossing, or hybridizing, the Little Club wheat with other varieties. He found that, whichever plant (variety) was used as the pollen parent, the next generation always showed the same group of characters. This is in accordance with what we have learned as Mendel's law of *dominance.* He also found that in the offspring of the hybrids every possible combination of the grandparents' characters occurred. This is in accordance with the law of *segregation.*

By selecting individuals in this third generation and growing from their seed, and by keeping careful and complete records of the results, Mr. Spillman succeeded in finding the strains that had the necessary elements in their germ cells and so transmitted the desired combinations of characters, in accordance with the law of *combinations* or the law of *unit characters.* In

this way it was possible to combine in one variety of wheat the strong stem, the closed head, and the winter-resisting qualities needed for successful farming in this region. By similar methods it has been *possible to combine three or more characters desired in a plant* from as many different varieties of ancestors.

376. Breeding for immunity. The chief problem is to get organisms that combine desirable qualities and show none of the undesirable qualities. It is not possible, as we have seen, to transmit all the characters appearing in a combination formed by hybridizing, or even in a combination resulting from segregation. *It is necessary that the elements from the two parental gametes which determine a given character shall be either both dominant or both recessive.* If only one of them is dominant, the particular individual may have the quality in which we are interested, but its offspring will be of two kinds (see Fig. 215). In the case of wheat, immunity to rust is recessive. It is thus possible to establish strains of wheat that combine immunity with other desirable qualities; for, as we have seen, it is only necessary to breed the hybrids into the following generation in order to get a complete segregation of the various qualities and their different combinations. From the third generation we can then select the offspring that appear in a pure recessive or in a pure dominant condition.[1]

377. Practical breeding. The failure of their hybrids to breed true has been the despair of plant and animal breeders in the past. Only those were successful who, like Luther Burbank, were patient enough to try out vast numbers of hybrids and keen enough to detect the rare individuals that would breed true with regard to the desirable qualities or combinations. With the discoveries of the principles of heredity every intelligent fancier or breeder can produce new varieties of organisms without limit, obtaining almost any combination of useful or fancy characters that he may desire. When Burbank produced a "white blackberry," he did not get a plant with a *new char-*

[1] Of course it is not necessary to carry the test so far with plants that can be propagated vegetatively.

acter, in a strict biological sense. He combined a plant having pale yellow berries with one having large, black berries—the Lawton blackberry. From the hybrids he obtained segregating offspring, and from the latter he was able to *fix* the individuals that combined lack of pigment with some other desirable

Fig. 217. Spineless cactus (*Opuntia*)

This variety was established by Luther Burbank through experimentation. It grows in arid soil that is otherwise useless, and promises to become a valuable fodder for horses and cattle. (From photograph lent by Mr. Burbank)

qualities in a pure state. Another new "creation" of Luther Burbank's is the spineless cactus, which is shown in Fig. 217.

Every year the experiment stations and the private gardens of seed producers, nurserymen, and horticulturists offer us "new" flowers, fruits, and vegetables. Those that have to be grown from seeds every year are the result of careful experiments designed to discover the segregated individuals that have the desired or usable combinations of characters. Those that

can be propagated vegetatively are also for the most part the results of hybridization. Occasionally a new variety is based on a chance mutation which continues to breed true. The Dutch botanist Hugo de Vries obtained eight different mutations of evening primrose, as well as others in various species of plants. Through these methods it is now possible to improve the quality of plants; for example, quality of cotton, quick ripening, resistance to disease, and so on. It is possible also to make special breeds for particular localities that are suitable only for plants with special combinations of characters.

PLANT BREEDING

1. Induced variations in plants
    - Why variation is desired (increased chance of finding more useful types)
    - How variations are induced
        - Maintaining best living conditions for plants
            - Expectation that all possibilities will come out
        - Changing conditions in detail
            - Expectation that individuals will develop new characters
        - Hybridization (crossing individuals that differ)
            - Expectation that offspring will show new combinations of characters or extreme degrees of some characters
2. Instability of offspring from induced variation
    - Fluctuations, depending on the conditions, do not reproduce themselves
    - Hybrids "split up" or "throw back" to ancestral types
3. Preservation of new variations by vegetative methods
    - Propagation
        - Tuber; bulb; cuttings; layering
    - Grafting
4. Laws of heredity (Mendel's principles)
    - Dominance
    - Segregation
    - Combination (unit characters)
5. Practical breeding
    - Find variations or mutations and see whether or not they breed true

Hybridize plants having desirable qualities
  Inbreed hybrids for segregation
  Try out third generation for combinations that are pure
  Multiply by seeding the true breeders; destroy all others
  Select hybrids that are worth keeping
  Propagate vegetatively

QUESTIONS

1. How do the common vegetables in use today differ from those used a generation ago?

2. How do the common fruits in use today differ from those used a generation ago?

3. How are the changes brought about?

4. What advantages has the plant breeder over the animal breeder?

5. What are the necessary steps in establishing a new breed of plants?

6. Are all the new plants superior to all the old ones?

7. Why are different varieties of wheat grown in different parts of the wheat-growing region of this country?

8. Why are different varieties of fruit grown in different parts of the areas that produce the same kinds?

9. What advantages have come from Mendel's discoveries?

REFERENCE READINGS

OSTERHOUT, W. J. V. Experiments with Plants, chap. x, Making New Kinds of Plants.

JEWETT, F. G. The Next Generation, chap. iv, Mendel and his Garden Peas; chap. v, Laws of Inheritance put to Use.

Farmers' Bulletin 1243, Strawberry Varieties in the United States.

Farmers' Bulletin 1332, Seed Potatoes and How to Produce Them.

United States Department of Agriculture. *Bulletin 195*, Potato Breeding and Selection.

United States Department of Agriculture. *Bulletin 1192*, Improvement of Wheat by Pure-Line Selection.

United States Department of Agriculture. *Bulletin 1209*, Effects of Selection on Yield of Corn.

CHAPTER XLVI

ANIMAL BREEDING

Questions. **1.** How can animals be made to lose qualities or to take on new ones? **2.** Are the results of training passed on to the next generation? **3.** If dogs' tails were cut off each generation, would the breed finally lose the tail? **4.** Are acquired characters inherited? **5.** Can all kinds of animals be domesticated? **6.** Can two animals of different species produce offspring? **7.** Are all hybrids sterile like the mule? **8.** What is there to show that modern varieties are really different from their ancestors? **9.** Do animals in a state of nature become changed the way domestic animals do?

378. Domestic animals. We have no exact history of the beginnings of man's domestication of animals, but indirectly we can tell that this relationship has extended over many thousands of years. The total number of species is really not very great; the remarkable thing is the tremendous amount of variation within each species. Anyone who has ever attended a dog show or a poultry show, for example, cannot help wondering where all the varieties came from and how they were produced.

With very few exceptions all the domesticated animals are vertebrates, chiefly mammals and a few birds. The dog, the horse, the ox, the sheep, and the pig represent the principal groups of domesticated animals. The cat has been at home in our dwellings for at least three thousand years, but it does not approach the others in importance, either as a companion or as a serviceable animal. The camel and the elephant have been domesticated in Africa and Asia. Many other animals have been cultivated as pets, such as rabbits, mice, guinea pigs, and even skunks, woodchucks, and squirrels. In recent years attempts have been made to develop farms for fur-bearing animals such as the silver fox and the muskrat, and these have met

with some success; but these animals are not yet domesticated, and they are not yet a part of the breeder's problem.

Among the birds the common hen is the most important, ducks and geese and turkeys coming next. The pea fowl, the guinea fowl, and other species have been kept in flocks; parrots, canaries, and others have been kept as pets; and attempts have been made to domesticate many "wild" species.

Fish culture has developed rapidly in modern times, but outside of the goldfish and a few other forms that are kept in jars we can hardly call any of them domesticated. Brooks and lakes have been stocked with young fry or with fertilized eggs, and bodies of water have been protected so as to give the fish a chance to multiply, but they have not been cared for in the same way as our goats and cows. A few invertebrates fall under the care of the fish-culture activities of the Bureau of Fisheries—oysters, mussels, and lobsters, for example; but these are not, strictly speaking, cultivated as are chickens and dogs.

Among the insects the honeybee and the silkworm are truly domesticated animals. There are many varieties in both species, and close attention is given to the conditions of their living and to protection from dangers or enemies.

The animals that man has attached to himself, while they differ in many ways from each other, must have certain qualities that make domestication possible. The dog, for example, although related to the wolf, has a disposition that permits him to learn to live in a way that will make him acceptable. The horse, the cow, the sheep, and the pig submit to man's mastery. It is possible, however, that many other species that are not now domesticated could be made to live under our control if we caught them young and used our skill in adjusting them to our needs; for all the wild animals in the menagerie and in the zoölogical gardens show a great deal of adjustment to life under artificial conditions. Moreover, in Africa and Asia there are still species of wild horses that, when caught young and broken to the saddle or harness, are just as serviceable as those born and brought up on farms.

379. The problem of animal breeding. Every domestic species has many more or less distinct varieties. In fact, the outward differences between two breeds of dogs or horses, for example, may be greater than we sometimes observe between two distinct species. The breeder's problem is, first of all, to find the variety or breed that is of greatest value or most suitable for his particular purposes. The next problem is to obtain a continuation of the desirable qualities generation after generation. The Blue Andalusian fowl is a bird that has won prizes at poultry shows and has some desirable qualities, but breeders

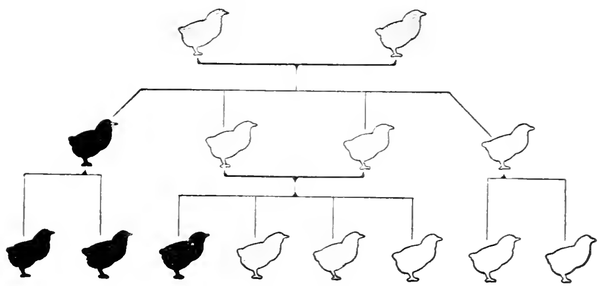


Fig. 218. Color inheritance in the Blue Andalusian fowl

When good specimens of this variety are mated, their offspring produce on the average only 50 per cent of good Andalusian Blues; the rest are about evenly divided between white chickens and black chickens. The Blue Andalusian is a hybrid; the only way to get 100 per cent of birds of this kind is to mate a white and a black parent. (From Jewett's "The Next Generation")

have been unable to get this variety in a pure breed. If we could cut up a Blue Andalusian hen into a hundred or a dozen pieces, as the plant breeder does with some of his prize specimens, and then get each piece to grow into a complete hen, we might make some progress in fixing this variety. But this method of propagation is not usable with animals. Each generation has to reproduce by means of eggs and sperms, and that means the danger that hybrids will split up (see Fig. 218).

Another side of this problem is illustrated by the common mule. This animal is a hybrid also—between the male of the ass and the female of the horse. The mule differs from both

parents in several ways, but has many useful qualities. He can stand more hardship than the horse, can do much more work on less food, can stand rougher roads, and is very sure-footed. He has some disagreeable traits also, but his good points are enough to make people tolerate him. It is impossible to establish a pure race of mules, however, for the simple reason that this hybrid is incapable of reproducing itself; each generation of mules is raised anew by crossing a mare and an ass. If the mule were not sterile, it is probable that his offspring would "split" into several kinds of individuals showing various combinations of horse and ass characters.

380. Mendel's principles apply to animals. As we have already seen, Mendel's principles of heredity apply to animals as well as to plants. A knowledge of these principles has completely changed the practice of animal breeding during the past twenty-five years. The fact of dominance is well illustrated by the horn of cattle. Occasionally there appears an animal without horns; the Polled Angus was a mutation of this kind. The absence of horns is a desirable quality. If a polled, or hornless, individual is mated with one that has horns, all the offspring will be without horns; a pure-bred hornless bull may thus become the ancestor of whole herds of hornless cattle; but if hybrid polled animals are mated, the following generation will show *segregation* in the way already described for the yellow-green pea and other plant characters (see section 373). The table on the opposite page shows how succeeding generations of sheep or cattle will behave with respect to the appearance or non-appearance of horns.

In some species of animals the presence of pigment is dominant over the absence of pigment—as in rabbits, mice, and guinea pigs. Among the white leghorn fowls, however, whiteness is dominant to pigmentation. In the Andalusian fowl, as we saw above, there is no complete dominance either of whiteness or of pigmentation, but the segregation is complete. The short-haired coat of guinea pigs is dominant to the long-haired coat (see table on page 524).

RESULTS OF INBREEDING HYBRIDS FROM HORNED AND POLLED CATTLE[1]

Parent Generation	First Hybrid Generation	Second Hybrid Generation	Third Hybrid Generation	Fourth Hybrid Generation
		Polled	POLLED	POLLED
			Polled	POLLED
				Polled
	Polled	Polled	Polled	Polled
		Polled	Polled	Polled
				Horned
			Horned	HORNED
		Horned	HORNED	HORNED
		Polled	POLLED	POLLED
			Polled	POLLED
				Polled
	Polled	Polled	Polled	Polled
		Polled	Polled	Polled
				Horned
			Horned	HORNED
POLLED × HORNED		Horned	HORNED	HORNED
		Polled	POLLED	POLLED
			Polled	POLLED
				Polled
	Polled	Polled	Polled	Polled
		Polled	Polled	Polled
				Horned
			Horned	HORNED
		Horned	HORNED	HORNED
		Polled	POLLED	POLLED
			Polled	POLLED
				Polled
	Polled	Polled	Polled	Polled
		Polled	Polled	Polled
				Horned
			Horned	HORNED
		Horned	HORNED	HORNED

[1] See note on page 511.

HEREDITY IN ANIMALS

Name of Animal	Dominant Character	Recessive Character
Cattle	Hornlessness	Horns
Horse	Trotting	Pacing
Silkworm	Yellow cocoon	White cocoon
Rabbits, Guinea pig	Short fur	Angora fur
Mice	Normal movements	Waltzing habit
Mice, Rabbits, Guinea pig	Pigmented coat	White coat
Leghorn poultry	White plumage	Pigmented plumage
Salamander	Dark color	Light color
Canary	Crested head	Plain head
Poultry	Rose comb	Single comb
Poultry	Short rump	Long tail
Land snail	Plain shell	Banded shell
Pomace flies	Red eyes	White eyes

In raising sheep certain kinds of fleece are found to be more profitable than others. In order to combine such a desirable quality with some others, it would be necessary first to find out which characters were dominant and which recessive, then hybrids would be produced and inbred until the segregation appeared in the third generation. Next, individuals having desirable combinations of characters would be picked out for further multiplication.

381. The law of combination. The law of unit characters, which makes possible the establishment of individuals with new combinations of characters, applies to animals, as do the other Mendelian principles. In the guinea pig, for example, we can combine long hair from one parent with white coat from another, or short hair from one parent with blackness from another (see Fig. 219). Many of the breeds of cattle raised on the large prairie ranches of the Middle West have excellent beef qualities and are easily handled in large herds, but most of them are susceptible to the destructive Texas fever, which has caused the

death of vast numbers. The Brahmin cattle of India, however, are immune to Texas fever. When these immune animals are mated with the susceptible varieties, the hybrid offspring are all immune; that is, immunity in this case is dominant. Brahmin cattle were accordingly imported for crossing with our native cattle, in order to establish a variety having the beef qualities of American varieties with the immunity to Texas fever.[1]

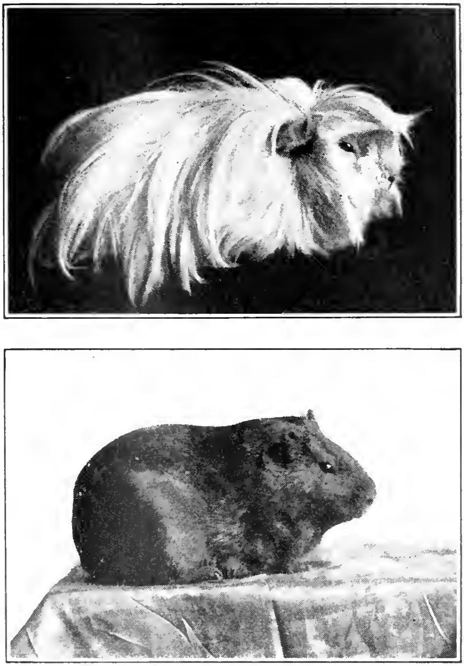


Fig. 219. The law of unit characters illustrated by guinea pigs

Pigmentation in these animals is dominant over albinism. Short hair is dominant over long hair. Rough coat is dominant over smooth coat. When two pure individuals like those shown are mated, the offspring will be short-haired, dark, and rough-coated. On mating the hybrids together in sufficient numbers the segregation will result in producing every combination of these three sets of characters: dark-short-rough; dark-short-smooth; dark-long-rough; dark-long-smooth; white-short-rough; white-short-smooth; white-long-rough; white-long-smooth. The proportions will be such that *for each pair of contrasted characters* there will be one recessive to every three dominants. (From photographs lent by Professor W. E. Castle)

[1] In the meantime it has been found out that the Texas fever is transmitted by a little animal known as the tick, which sucks the blood from the diseased cattle. By suitable quarantine it has been possible to restrict the Texas fever; and by applying to the bodies of the cattle something that will either kill the ticks or prevent their biting the cattle, it may be possible to eradicate this costly disease. But if we could replace our present herds of cattle with a type that is quite immune, the added cost would no doubt be made up in a very short time.

Today breeders apply these principles and produce varieties of animals that are new in the sense that they have *combinations* of qualities that have never appeared before. The Orpington fowl is an artificial breed of this kind, and new breeds are being brought out every year, both among the strictly utilitarian varieties and among the fancy breeds, or pet animals, such as dogs, pigeons, cats, rabbits, and so on.

The breeder looks in the third generation (the segregating generation) for individuals that have the desired combination of characters, all in a pure state. He then proceeds to multiply his stock by inbreeding, that is, by mating similar types, or members of the same litter, for several generations. It has been found that this inbreeding, instead of causing degeneration, as was formerly believed, only tends to bring out and fix the characters that are present from both lines of ancestry. Of course, if there are any undesirable characters, these will also become fixed. Outbreeding, or the mating of individuals having diverse ancestry, is now practiced by breeders only for the purpose of making new combinations of characters in the hope of discovering more valuable or more interesting varieties.

One form of inbreeding which is of great value is that of "grading up" stock. Pure-blooded animals are very rare and very expensive. It is not possible for most farmers or raisers to replace their poor stock with pure-bred animals. Accordingly they get the services of a pure-bred male for their flock or herd. The following generation of hybrids will be 50 per cent pure bred. The following generation is again served by the same male, and the grade is further advanced. In the course of a few years or generations the scrub, or mixed, varieties are replaced with high-grade animals at a comparatively low cost to the owner.

382. The value of animal breeding. Within recent times a great change has been brought about in the character of the animals under cultivation. In some parts of the country the farmers have not yet discovered that the old breeds ought to be replaced. In a survey of dairy cattle made a few years ago in

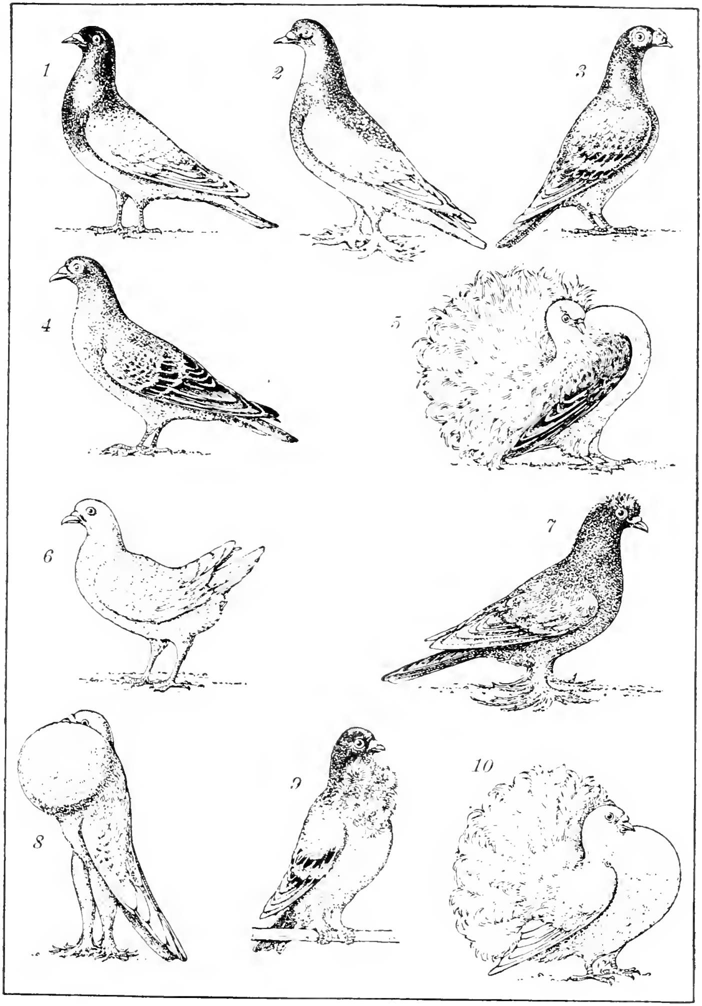


Fig. 220. Varieties of cultivated pigeons

All these varieties, and many others, have been developed in recent times from the same stock or ancestry. A knowledge of heredity enables the fancier to obtain new combinations of characters in a few generations. *1*, Silver Runt; *2*, Muffed Tumbler; *3*, Dragoon; *4*, Homer; *5*, Saddle Fan-tail; *6*, White Maltese; *7*, English Red Trumpeter; *8*, White Pouter; *9*, English Owl; *10*, White Fan-tail

one of the states it was found that about a fourth of the cows yielded so little milk that they did not pay for their keep, while another fourth barely paid for their keep but left no profit to their owners. Some cows produce from four to six times as much milk as others for the same amount of care and feed. Some hens produce from two to three times as many eggs per year as others for the same amount of attention and feeding. The bantam fowl, which is similar to the ancestor of all our modern poultry, laid perhaps from twenty to thirty eggs a year. The best breeds of today have produced hens with a steady yield of over two hundred eggs, with record-breakers of over three hundred eggs.

For certain purposes the amount of fat, which is converted into butter, may be of more importance than the total yield of milk. Through the use of the Babcock test, which was invented by a professor at the University of Wisconsin and donated by him to the public, it is possible for the dairyman to determine very quickly what percentage of fat there is in a sample of milk. In this way he can keep track of what each cow in the herd is doing from day to day. This has been of substantial help in selecting and breeding for high fat production.

383. Practical theory. Everybody knows that by practice you can improve your form and your performance in athletics. The same is true of penmanship or of playing the piano. Moreover, the principle of improvement through practice or training applies also to other living things. The people who are raising horses, for example, will tell you that training stables and running tracks are necessary parts of the equipment. If we are going to raise fast horses, one of the things to do is to use as parents animals with a record for fast running or trotting. We should also like to get animals whose *ancestors* have good records. To a person who is going to buy a high-bred horse the pedigree is just as important as a medical certificate. Finally, we should want to try out our young horses to find out just how fast they are. Now one of the questions that often comes up in

connection with horse-raising is this: Will the training which the horse gets influence the quality of his offspring? Will a mare that has had track training produce faster colts than a mare who has not had training? Our present knowledge would lead us to say that the mare's training would *not* influence the offspring. What the training does is to enable the horse-breeder to pick the most promising individuals to be the parents of the next generation.

ANIMAL BREEDING

1. Kinds of animals cultivated by man

Mammals	Birds	Insects
Horse	Hen	Honeybee
Ox	Turkey	Silk moth
Sheep	Duck	(Crustaceans)
Pig	Goose	Lobsters
Dog	Pigeon	Crabs
Goat	Peafowl	(Mollusks)
Reindeer	Guinea fowl	Oysters
Camel	(Fish)	Mussels
Elephant		
Cat		

2. Induced variations in animals
    - Why variations are desirable
        - Increase chances for new qualities
    - How variations are induced
        - Providing most favorable conditions
        - Changing conditions
        - Training or practice
        - Hybridization
3. Instability of variations
    - Fluctuations
    - Acquired characters
    - Hybrids
        - Either sterile or split up
4. Laws of heredity
    - Dominance
    - Segregation
    - Recombination

5. Producing new varieties
    - Find mutation or desirable type
    - Hybridize (outbreed)
    - Inbreed hybrids for segregation
    - Try out selected combinations for pure breeding
    - Inbreed to fix type
    - Multiply
    - Destroy undesirable and unstable forms
6. Improving quality of herd or flock
    - Grading up
7. Value of animal breeding
    - Increase yield (milk, eggs, fat, silk, wool)
    - Improve quality of yield (finer fiber, finer meat, faster)
    - Examples from current developments
        - Cows; horses; hens; sheep; pigs; dogs

QUESTIONS

1. What qualities would make one kind of animal more easily domesticated than another?

2. What qualities in an animal would make it more worth while to domesticate?

3. What is the value of the reindeer as a domestic animal? of the goat? of the camel?

4. Why are different breeds of cattle prevalent in different parts of the country?

5. What new varieties of animals have been recently developed or introduced in your community or region?

6. How many different varieties of dog do you know? of pigeon? of cat?

7. In what respects do the various breeds of cow differ from each other? of chicken? of horse?

8. Is the use of horses increasing or decreasing in the country as a whole? Why? Is this equally true in all regions? Why? Is this equally true of all varieties of horse? Why?

9. What are the best egg-layers in your region or county? What are their records? Of what breed are they? How do their records compare with others of the same breed? of different breeds?

10. What are the best milk producers in your county or state? What are their records? Of what breed are they? How do their records compare with others of the same breed? of different breeds?

11. For what purposes is butter fat more important than total yield?

12. What are the advantages of white eggs over brown ones? What are the disadvantages?

13. How is the Babcock test carried out? On what principles is it based?

14. Why is it important to know whether a given character in an animal is acquired or inherited? How can we find out?

15. Why is it important to know whether acquired characters may be transmitted? What reasons are there for believing that they are transmitted? that they are not?

REFERENCE READINGS

Waters, H. J. Essentials of the New Agriculture, chaps. xvi, xviii–xxiii.
Farmers' Bulletin 1327, Canaries, their Care and Management.
Farmers' Bulletin 1373, Homing Pigeons.
Farmers' Bulletin 525, Raising Guinea Pigs.
Farmers' Bulletin 1090, Rabbit-Raising.
Farmers' Bulletin 1167, Essentials of Animal Breeding.
United States Department of Agriculture. *Bulletin 905*, Principles of Animal Breeding.
Farmers' Bulletin 893, Breeds of Dairy Cattle.
Farmers' Bulletin 1263, Breeds of Swine.
Farmers' Bulletin 576, Breeds of Sheep.
Farmers' Bulletin 619, Breeds of Draft Horses.
Farmers' Bulletin 952, Breeds of Light Horses.
United States Department of Agriculture. Yearbook for 1916. Reprint 748, Coöperative Bull Associations.
Farmers' Bulletin 1221, Ornamental Breeds of Chickens.

CONSERVATION

CHAPTER XLVII

THE EARTH FOR MANKIND

Questions. **1.** Does the earth support all the life that is possible on it? **2.** How could the total amount of life be increased? **3.** Would it be desirable to increase the total amount of life? **4.** Would it be desirable to increase the total amount of human life? **5.** Would it be desirable to exterminate any form of life? What would be the effect of changing the balance of nature?

6. Why cannot every individual plant or animal that is born reach maturity? What would happen if they did? **7.** How does each species of animal and plant come to fit so well into its particular surroundings? **8.** Can an animal do as well in new surroundings as it can in its natural environment? **9.** Is there really room for all the people who are born? **10.** Should not a nation try to make itself independent of others for all its needs?

384. Interdependence of life forms. All living things must have food and water and air and a foothold. Since they all depend upon the same sources of supply, there must be a limit to the number of organisms that a given area can support; and that means that somewhere there must be a limit to the total amount of life which the whole earth can support. In a pond, for example, some of the plant life consists of algæ and of larger plants that bear seeds. These chlorophyl-bearing plants condense sunlight: that is, by means of sunlight energy they convert carbon (from carbon dioxid) and hydrogen and oxygen into carbohydrates, which are the basis for the energy of all protoplasmic activity. The protozoa and microscopic worms and crustaceans live upon one another; the fish and mussels and larger crustaceans and worms live upon the smaller animals.

The total amount of animal life in the pond is limited by the total amount of plant life. This fundamental interrelation of chlorophyl life and non-chlorophyl life sets the limit to the total amount of protoplasm that the pond can support. In an aquarium we can bring about a *balance* between the amount of plant life and the amount of animal life, so that it may continue indefinitely without the addition of anything from the outside except fresh water to make up for evaporation.

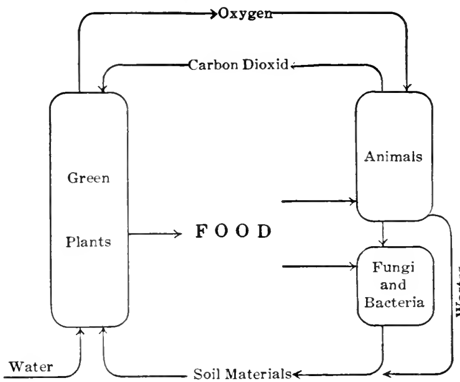


Fig. 221. The interrelations of organisms

The green plants, using water and carbon dioxid and salts from the soil, are the source of all food and the source of much oxygen derived from the decomposition of carbon dioxid (during photosynthesis). The food is used by animals and by lower plants (fungi and bacteria), and in the end the substance of the animals is also used by the fungi and bacteria. The carbon dioxid given off by the animals and by the fungi and bacteria sooner or later finds its way back to the green plants through the air or water. Other wastes given off by these organisms are the raw material which in time becomes the food that green plants absorb from the soil

This *balance* between one kind of life and other kinds of life extends also to life on land and in the air. A single species of animal could not live by itself. Neither man nor the ameba could live unless there were at least some green plants also. The balance of life includes the fact that the many different kinds of plants and animals fit into a total that makes possible the largest amount of protoplasm.

385. The struggle for existence. Every animal is constantly destroying other life (or using material from organisms that have already died), and it is also in danger of being destroyed by some other living thing—plant or animal. It is therefore impossible for *every* new individual organism to reach its full

development and to reproduce itself. *If* all the eggs laid by a single house fly in the spring reached maturity, and each female laid her usual number of eggs, and these all developed, and so on through the summer, there would result a mountain of flies as large as a good-sized city. *If* the eggs of any variety of fish all developed into adults and reproduced in this way for only a few generations, they would fill up the whole ocean. But here are too many conditions that cannot be fulfilled. There is the food supply: What is the food, and is there enough for all the fly maggots or all the fish fry? There is the presence of enemies: Can every egg escape the bacteria and insects and fungi that inhabit the manure heap? Or can every fish egg escape the bacteria and fungi and crustaceans and other fish that swarm in the sea? Putting the situation in another way, *it is impossible for all animals to grow up*, because growing up itself means the destruction of animals.

Now the destruction of life is going on all the time, just as the making of new protoplasm is going on all the time; and one process depends upon the other. There is no life without death. The growing body carries on by destroying part of its own protoplasm—the life's energies come from the oxidation of protoplasm material; and the living body grows by obtaining the protoplasm products of other organisms. The result of this relation is the process which has been called **the struggle for existence**. The idea is that in its struggle to maintain itself life is in perpetual conflict with its surroundings. When the temperature gets very low, many seeds or young plants and many eggs or young animals may freeze to death. Here protoplasm struggles to live in a falling temperature. In the woods some plants grow faster than others; the shaded ones may be unable to get sufficient light to produce all the carbohydrates they need, and they finally perish. Here protoplasm struggles toward the light. Down on the ground, in the shade of the trees, some plants manage to get enough light to live on, while others are shaded to death, just as some seeds manage to survive the cold spell, while others do not. Again, during a period of drought

some of the plants will be killed; their struggle for water is unsuccessful. Other plants, with perhaps deeper roots or thicker epidermis, remain alive until a new supply of water arrives.

No matter what plant or animal we consider, we find that the conditions of life are such that *it is impossible for all to survive.* There is a struggle for every individual from the very first moment of life. The struggle is along several different lines. (1) Every organism is exposed to variations in external conditions (temperature, moisture, light, chemical conditions) in the air, in the water, in the soil. (2) Every organism is subject to attack by other organisms—parasites and predatory enemies. (3) Every organism is in need of food and must somehow get its supplies. It may mean hunting or lying in wait; it may mean depending upon the wind to bring it to a favorable location, as with spores of fungi or with bacteria; it may mean actually fighting for it, with members of the same species or with members of other species. In every direction, then, each individual organism is in the midst of a struggle, most factors of which are quite beyond its ability to control in any way; and of course with most organisms there is no question of knowing anything about it or doing anything intelligent about it. It is for most organisms (individuals) largely a matter of chance whether they die sooner or later.

386. The meaning of fitness. Most of the new individuals (spores, seeds, eggs) are prevented from reaching maturity. What determines which ones are destroyed all along the road from infancy to maturity, and which ones reach the end of the journey? The expression *survival of the fittest* summarizes the results; but, while it is a true expression, it is also misleading. Many of us are apt to conclude that *fittest* has some moral or religious significance; but that is not the intention. The fittest rabbit when rabbits are being chased by dogs or foxes is the swiftest rabbit. The fittest rabbit when a severe frost attacks the tribe is the one with the best fur or the one that has stored up the most fat under his skin during the previous summer and autumn. The fittest fish is the one that can dart away quickest

when pursued by a larger one, or the one that can catch his prey quickest when there are smaller ones around, or the one that is able to make use of a great variety of food. There is no absolute standard for plants or animals. *Fitness is a relation between the organism and all of its surroundings,* including possible enemies and possible food, changes in physical conditions and in seasons. The wolf and the vulture are just as fit as the sheep and the chicken. The thistle and the ragweed are just as fit as the sunflower and the pansy. But no plant species and no animal species can altogether fit in where some other one is living. The fitness is of a special kind that has taken hundreds of thousands of years to attain. When conditions in any region change radically, we can see that the whole character of the vegetation changes, and also the character of the animal life.

387. A weeding-out process. Only a small fraction of each new generation can survive. The majority is always destroyed. Which particular ones are destroyed is determined by a multitude of details—details of structure, details of response, details of activity. All the details together bring about a degree of fitness to the total surroundings—or lack of fitness. One animal was killed early because it was too slow, another because it moved into the open too soon, before its enemy was out of sight. One animal was killed because the tapeworm in its intestines was too much for it; another because it was too conspicuous on a tree, and a bird caught it. On the whole the total qualities of the surviving members of a species are probably better suited to the particular conditions of life than the total qualities of those members who perished. Charles Darwin gave the name *natural selection* to this process whereby the least adaptable members of a species are weeded out, leaving the most adaptable ones to survive and reproduce themselves. Can we imagine that the weakest or the slowest or the most easily wilted or winded individuals would survive? Of course not. So far the expression *natural selection* is simply a shorthand phrase for describing exactly what our common sense would lead us to expect; and Darwin used this term not to imply that nature

picks out what she wants to preserve, or favors one group at the expense of another, but to emphasize a process which is evident enough, in order to offer a possible explanation for something that is not so clear. For example, we know that in different parts of the world there are species of animals or plants that are of the same family but different in many details. The grasses of the tropics are different from those of the temperate zones, and these differ from those farther north or south; and each species seems to fit better into its surroundings than some related but different species would. The same is true of animals. Another important fact is that the species of plants and animals that lived in past ages resemble those of today in some respects, yet are different. We have seen that in the course of years the cultivators of plants and animals have gradually brought about changes in the domestic varieties of organisms. It was artificial selection that gave us tumbler pigeons and fine poultry, high-grade wheats and many varieties of cabbage. Now Darwin supposed that a similar process takes place in nature; the less favored individuals are destroyed and the more favored ones (that is, those better adapted to their life conditions) survive and leave offspring. There is always a great deal of individual variation, and more individuals are always started than can possibly reach maturity. This selection, generation by generation, ought in the course of long ages to establish in each locality those varieties that were best adapted to the conditions.

We have seen (sect. 367) that many of the variations among individuals are not inherited. The selection would have to take place in each generation if the qualities were to be preserved or accumulated. There are other qualities, however, which are inherited and which may help in survival. Moreover, there are probably mutations of some degree appearing all the time, and these may play an important part in the gradual change of species as time goes on. In Darwin's time it was not realized either that the ordinary fluctuations were not inherited or that mutations are so frequent and more stable.

388. Man's struggle. As a living being man has to meet the conditions of life just as truly as do other organisms. In some

ways the human machine is decidedly inferior to other organisms. For example, man's skin is much more tender than that of any other animal of his size, and the hairy covering is not a great protection from unfavorable weather. When it comes to fighting, his nails are far inferior to cat's claws, let us say; and his teeth, which he does indeed sometimes use, are not nearly so formidable as are those of many smaller animals. His muscular development too is rather inferior when it comes to wrestling with a non-human enemy; and when it comes to running away or to catching his prey, many of the inhabitants of the forest are much swifter.

Man has a very good eye compared to other animals, and a pretty good ear, though not one of the best for discovering faint sounds: but his smelling ability is of rather low rank. These three senses, which are so valuable to animals in helping them discover their enemies or their food at a distance, are of great help to man also; but on the whole he has no advantage in competition with other inhabitants of the forest.

In spite of these various shortcomings man has contrived to hold his own, and some branches of the species have become virtually masters of their environment, *through the use of the brain.* With this brain man has made up for his thin skin by borrowing the skins of other animals and by devising substitutes for skins out of other materials. He has strengthened his arms by means of sticks and stones, and has lengthened his legs (that is, increased his speed) by means of iron and brass. He has extended the reach of his eyesight millions of miles beyond the surface of the earth, and has seen into the world of the little—a thing no other backboned animal has ever done. He can hear the footsteps of a fly, and he has caught vibrations through miles of space. In every direction man has made up for his organic insufficiency by using the thinking organ to guide his hand.

The struggle of man to control his natural environment has succeeded largely because of the use of intelligence far in excess of that shown by any other species of living thing. A part of his strength has come from the tendency to form groups, with

division of labor and good teamwork. Those who think of the struggle for life in a simple, shortsighted way sometimes imagine that the greatest gain to individuals, and therefore to the race, comes when each one tries to get the best of his neighbors; but the experience of the race and everyday observation convince us that the great gains have been made through coöperation and joint action. The principle of community action is

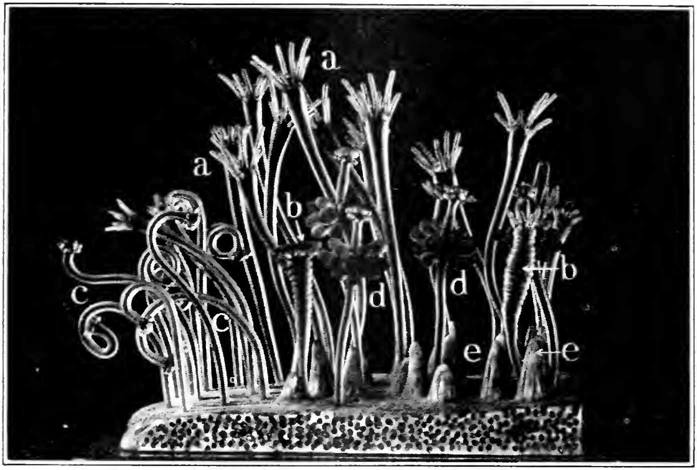


Fig. 222. Colony of *Hydractinia*

In this colonial animal (related to the jellyfish and to corals), as in many others, there are distinct kinds of individuals, called *hydranths*. *a*, vegetative, or food-getting, hydranths, which take in and digest food for the whole colony; *b*, vegetative hydranths in various stages of contraction; *c*, protective, or fighting, hydranths, which bear large numbers of nettling cells; *d*, reproductive hydranths, male and female, which throw off sperm cells and egg cells respectively; *e*, buds, or undeveloped hydranths. (Photograph from model in American Museum of Natural History)

illustrated at every level of life, and is in fact the basis for all higher organisms; for we may well consider that a many-celled organism is one in which the lumps of protoplasm, instead of separating as fast as they are formed, remain in contact and gradually divide up the special functions among themselves. The division of labor is slight among the simplest many-celled organisms (the hydra and some algæ) and increases as we go

from these to the highest. Likewise, the cohesion of individuals, that is, their sticking together, and the division of labor are both rather weak among the lowest races of mankind and become more marked as we go from these to the highest.

The great drawback of such highly organized coöperative societies lies in the danger that they will grow too fast. A humane society saves many people who in a cruder civilization would die of one disease or another—many people who are not very competent and who would in a simpler society be unable to make a living. We do not expose our weaklings and cripples and aged on the rocks or in the desert; we help them with their burdens and carry them along. This ability to save the weak lowers the death rate among civilized people. This means that as time goes on we require that more and more people shall be supported on every acre of usable ground, and that more and more food and other material must be obtained for every day's work. This gives to man's struggle a totally different character from that which we see among other living things. It is no longer a question of swiftness or sharp teeth, of tough hide or long claws, of ability to stand punishment or cruelty in combat. It is more and more a question of skill and intelligence in utilizing both the resources and abilities of our bodies and the resources and conditions of our environment.

389. Intensive production. The first step in man's conquest of the earth was his learning to produce food by cultivating animals and plants instead of waiting for fisherman's luck—the finding and catching or killing of wild forms. Through steady improvements in the management of the soil and of crops there has been a steady improvement in the yield of man's efforts. To the weapons for defense against wild animals and for the hunt, man had added tools for work (see Fig. 223). The increase of production for labor expended has steadily continued. Sometimes the increase came from improvements in the manner of working, sometimes from improvements in the variety of organism cultivated, sometimes from improvement in the tools. In modern times man has been making systematic

efforts to increase his production by making improvements along every possible line. The chemistry of soil enables him to modify the soil in accordance with the needs of special crops. The use of machinery enables one man to plow a hundred

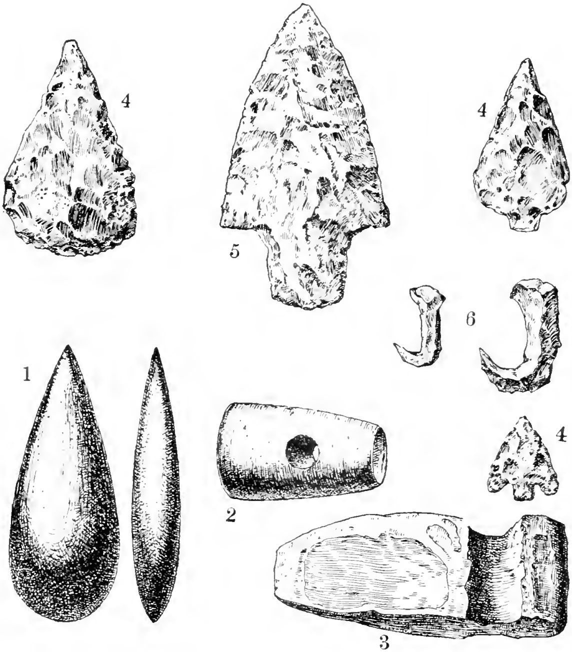


Fig. 223. Relics of man in the Stone Age

Remains of ancient times show that man made tools long before he discovered the use of metals. At first these were convenient sticks and stones, roughly shaped to fit the hand; later they were selected materials carefully worked over to suit definite purposes. *1*, hatchet; *2*, hammerhead; *3*, ax; *4*, *5*, arrowheads; *6*, fishhooks. (*1*, *2*, and *4*, after Tyler; *3*, *5*, and *6*, original)

acres in the time formerly needed for plowing one. It enables him to break the earth up more thoroughly, to cultivate more quickly, to harvest and thrash his grain with a fraction of the effort formerly required. The use of biology as applied to heredity enables him to increase the output of his acres and of

his cultivated animals from six to twenty fold. We can get some idea of the great advance of productivity in a comparatively short time by comparing the hours of labor necessary to produce various commodities at the close of the Civil War with the number of hours it took at the close of the nineteenth century (see table below). During the thirty years since these figures were compiled by the United States Bureau of Labor the improvements in most directions have been even greater.

COST IN HUMAN HOURS OF PRODUCING BY MACHINERY THE EQUIVALENT OF 1000 HOURS OF HAND WORK

Units of Value	Hours	Units of Value	Hours
Barley, 470 bu.	42.4	Books (binding), 2190 vols.	263.4
Corn, 220 bu.	151.3	Shoes, 45 pr.	135.0
Oats, 606 bu.	107.5	Newspapers, 1,750,000 pages	4.8
Potatoes, 2000 bu.	345.3	Envelopes, 230,000	72.6
Wheat, 310 bu.	46.0	Granite (dressing), 6150 sq.ft.	77.9

It is now possible for more people to live with a given amount of work, providing leisure for the many things that human beings value; or it is possible for each worker to get more leisure; or it is possible for each person to get more time for education in childhood or for travel and relaxation in later years; or it is possible for more people to be supported by each acre of cultivated land.

390. National food resources. Scientists are constantly engaged in solving problems connected with (1) producing more food on a given area, (2) utilizing materials to better and better advantage, (3) finding new sources of food, and (4) preventing food from being wasted; and of course the same kinds of effort are directed toward increasing and conserving our supplies of other organic materials.

Advances in chemical and biological knowledge have brought us new methods for preserving food for long periods. This makes possible a cheapening of food supplies in two ways: (1) It is possible to send food a long distance, from regions in which it is abundant to cities and countries where food is not

easily raised. (2) It enables us to keep the bulk of large crops for a longer period. The condensation or drying of milk, for example, makes the use of milk possible in places where cows cannot be kept; and it makes the surplus of the summer's milk available in the winter. Cheaper products have been applied to increasing our food resources, as in the development of cotton-seed oil for food purposes. By the use of modern methods we can convert cheaper oils into fine fats that take the place of more expensive butter for certain purposes. This fat has not the flavor or the vitamin A of good butter, but it supplies the fuel value, can be used for shortening, and has the further advantage that it does not turn rancid.

When the United States entered upon the World War, we all became aware of the importance of (1) more definite knowledge of national food resources, and (2) more systematic control of production, distribution, and utilization of food supplies. Arrangements were made to record every prospective bushel of grain or potatoes, every head of cattle, every catch of fish. Bulletins and proclamations were issued broadcast instructing all people how to get the most out of the food materials that they had, how to save every usable scrap of organic matter, how to make every square yard of cultivated ground yield more, how to preserve the food that could not be used up immediately. Canning and drying demonstrations, as well as cooking and gardening demonstrations, were made in all parts of the country, and for the first time in history a whole nation was brought together to face the food problem as a single family. The problem of food distribution also came to the fore.

As a result of the experience gained during the war, we now realize that it is not sufficient to provide warehouses and transportation for the year's production. It is necessary also to see that every child and every adult obtains an adequate supply of suitable nourishment. It is more important to the nation that every living unit be kept in good living condition than that a few individuals be given a chance to make profits out of speculation in things that the rest of us need.

There are many states in the Union that cannot possibly raise the food of all their inhabitants. Food has to be imported from other states that have a surplus of food. The same is coming to be true of large industrial areas in Europe. We see the same principle in the need for importing raw material, such as cotton or wool, into regions that use up vast quantities of materials in their industries. In the end, then, all civilized peoples come to be dependent upon one another. We might even say that civilization depends upon commerce, since only by this means can each region make the most of its resources and talents and at the same time get the benefit of what other regions can contribute. The coal-mining regions, for example, can be made to yield their coal only if their inhabitants can be supplied with food and clothing from other regions. The cattle-raising regions can be made to yield their products only if their inhabitants can get supplies of fuel and manufactured goods from other regions. So the whole world comes to be united.

To make possible more effective planning of agricultural production there was established, some years before the World War, an International Institute of Agriculture. This serves as a clearing house of information regarding crop conditions and yields, new methods in management, new varieties, dangerous pests, and other problems connected with getting the largest amount of plant and animal material from the earth for human use. We depend more and more upon international coöperation to insure an adequate supply of basic needs for all people.

391. Conservation. As pressure of population becomes greater we look about for increasing our supplies in two directions: (1) How can we produce more? (2) How can we get more out of what we have? The first problem, that of production, cannot be sharply separated from the second, that of saving or conserving, for a large part of the waste is tied up with our methods of production. A large part of each year's crop is lower than it should be because fungi and insects and mice and rats are allowed to destroy the plants, or parts of them, before the harvest. Our production is handicapped because we allow so

much of our soil to be wasted (see section 74). Making better use of what we have includes the reclamation of lands through drainage and irrigation (see Chapter VIII), and the elimination of weeds, plant and animal diseases, and other enemies.

In this country we have become aware of the need of a national conservation policy only within a comparatively short time. Until about the end of the nineteenth century most people thought nothing of the rapid destruction of our forests, the rapid exhaustion of our coal mines and other mineral resources, and the rapid ruining of many streams as sources of fish. All these results were accepted as part of the business of "developing" the country, each one trying to get all he could and leaving the next to take care of himself. But as Gifford Pinchot puts it, "Each generation has a right to all it needs, but no right whatever to waste what it does not need. Our children have their rights as well as we." It was under Mr. Pinchot's influence that President Roosevelt became the strong promoter of a national conservation policy.

THE EARTH FOR MANKIND

1. Interdependence of living things
    - Chlorophyl the basis of life
        - Oxygen cycle
        - Carbon-dioxid cycle
        - Nitrogen cycle
    - Food relations
        - Decay and scavenger feeding
        - Parasitic feeding
        - Predatory feeding
2. Struggle for existence
    - Life feeds upon life
        - Protoplasm destroyed in course of its activity
        - Protoplasm of others destroyed in growth
    - Reproduction in excess of means of subsistence
    - Struggle not a conscious or painful process for the most part
    - Directions of struggle
        - External conditions
            - Temperature
            - Moisture
            - Light
            - Chemical conditions
                - Air
                - Water
                - Soil

Food-getting
- Absorption
- Finding suitable location and food
  - Through outside agency (wind, water, etc.)
  - Through migration
  - Through pursuit
  - Through fighting
    - Members of own species
    - Other species

Escape from enemies
- Predatory enemies; parasitic enemies

Results of struggle
- Natural selection (elimination of the relatively less adapted)
- Survival of the fittest
  - Accumulation of favorable variations
  - Gradual replacement of older types
  - Increasing adaptation of life to special conditions

3. Man's struggle
   - Man's disadvantage as organism
     - Thin skin
     - Sparse hair
     - Weak muscles
     - Weak teeth and claws
     - Slow movements
     - Relatively dull senses
   - Man's advantages
     - Superior brain and intelligence
       - Enables him to utilize other organisms and inorganic resources to supplement his body
     - Disposition to social life
       - Leads to formation of large groups in which mutual aid is possible
       - Leads to division of labor and makes available for group great variety of talents
       - "In union there is strength"
4. Systematic mastery of material needs
   - Plant and animal cultivation versus fishing, hunting, root-digging, etc.
   - Use of tools in addition to weapons
   - Improvement of tools and development of machinery
   - Intensive cultivation
   - Better management
     - Of soil; of organisms
   - Improvement of types cultivated
     - Through selection; through breeding
     - Through exploration for suitable types

Development of commerce (exchange of goods)
- Advantages
  - Makes possible fuller utilization of resources and conditions of each region
  - Makes possible specialization and development of skill
- Disadvantages
  - Makes necessary handling and transportation of more and more material
  - Makes every region or nation dependent upon many others

5. The World War and national food problem
   - Survey of food resources
   - Systematic control
     - Of production
     - Of distribution
   - Public education for all people
     - On diet
     - On production
     - On preservation
   - Public realization
     - Of dependence upon adequate food supply
     - Of need for large-scale coördination and coöperation
6. Conservation
   - How to get the most out of our natural resources
   - How to get the most out of human labor
   - How to make best use of our materials

QUESTIONS

1. Of what advantage to any nation is a growing population? to the race as a whole? Of what disadvantage?

2. Is it desirable to increase the population of your community or state? Why? Of the world? Why?

3. Why do some states support more people per square mile than others? Could the same density of population be maintained in all?

4. What can be done to make possible large populations without undue crowding?

5. What animals or plants would it be desirable to exterminate from your region? Why?

6. How could the extermination of an undesirable plant or animal bring about undesirable consequences?

7. What do we need to know before undertaking to exterminate any species?

8. In what ways does the struggle for existence among animals resemble that among plants? In what ways are the two different?

9. How does the struggle for existence in man resemble that among other animals? How do the two differ?

10. What are the advantages that come to man from his social disposition? What are the disadvantages?

11. What other organisms show a high degree of social organization? In what respects is the social life in these organisms like man's? In what ways is it different?

12. What recent discoveries or inventions will be likely to increase the food supply?

13. What new discoveries or inventions can lower the cost of living without increasing the food supply?

14. How could improvements in health lower the cost of living?

15. What becomes of the time that is saved through new inventions or discoveries?

16. What organic materials go to waste in your community? What possible uses could be made of them?

17. What do you consider the most valuable organic resource of the country?

REFERENCE READINGS

Conn, H. W. Bacteria, Yeasts, and Molds in the Home, chap. iv, Mold Diseases.

Duggar, B. M. Fungous Diseases of Plants, pp. 7–8, 85–88, Methods of Control.

Farmers' Bulletin 1220, Grape Insect and Fungus Enemies.

United States Department of Agriculture. Yearbook for 1919. Reprint 802, Progress in Eradicating Contagious Animal Diseases.

Ward, C. H. Exploring Nature, pp. 140–148, "Natural Selection"; pp. 108–110, "Mimicry in Animals" (from Alfred Russel Wallace's "Tropical Nature").

Farmers' Bulletin 670, Field Mice as Farm and Orchard Pests.

Farmers' Bulletin 1329, The Boll-Weevil Problem.

Farmers' Bulletin 1444, Game Laws, 1924–1925.

CHAPTER XLVIII

THE FOREST IN RELATION TO MAN

Questions. **1.** What is the use of having forests if the trees are not cut? **2.** Why cannot forests be left to the management of their owners just as farms and other properties are? **3.** Of what use are trees in the city? **4.** Of what concern are forests to people who live in cities? **5.** Of what concern are forests to people who live along the seashore? **6.** How can the condition of the forests influence the cost of living? **7.** Why should public money be spent on recreation forests that are visited by only about 1 per cent of the people? **8.** Could a forest be run like a farm, to yield a product year after year?

392. Forest products. Man depends in many ways upon masses of trees growing together as forests. It is from the trees that we get one of the most useful of materials—wood. This is utilized in hundreds of ways, from the making of toothpicks and tool handles to the timbering of mines or the making of stock for newspapers. All human habitations have some wood in their composition, and probably most people live in houses built almost entirely of wood. Every home has furniture made at least in part of wood; and in every industry, and in every office, furniture and appliances made of wood are used.

In the railroad business millions of dollars are spent every year for the ties upon which the rails are laid. Similar amounts are spent upon telegraph poles and fence posts, although these are coming to be replaced by reënforced concrete and other materials. In shipping goods of all kinds from place to place millions of feet of lumber are used, in the form of packing cases and boxes and trunks. Trees furnish us with charcoal, turpentine, pitch, wood alcohol, and various gums and resins. From tropical trees we obtain rubber and quinin. To some extent the dye logwood is holding its own against the anilin blacks, and during the World War dyewoods took on a renewed importance because of the changes in the chemical industries. Bark from certain trees, especially the hemlock, yields tannin used in the tanning of leather.

The use of wood for fuel is not as great per capita as it was formerly, because we find it more profitable to burn coal, gas, oil, etc., and to use wood for other purposes. But every forest and every wood-lot produces annually large quantities of wood that cannot be used in the making of paper or of other useful things, and this may well be burned. Yet 42 per cent of the wood cut in this country every year is burned—a very wasteful way of managing our resources.

393. The forest and the air. Another use of the forest is found in the fact that through photosynthesis fresh supplies of oxygen are thrown into the air, replacing the carbon dioxid. In addition to this, the transpiration may be considered a help in that it keeps down the temperature of the plants and so of the surrounding air. The shade value of trees is highly appreciated in the summer time even by city dwellers, and the effect of trees in breaking the wind is appreciated in the winter time, especially by those living in the country.

394. The forest and water. On a bare hillside the water soaks down into the soil almost as fast as it falls, or it runs off, carrying particles of earth along in its course. On a hillside covered with a growth of trees the force of the falling raindrops is broken by the leaves of the trees, from which the water slides down to the ground along the twigs and larger stems. The rain that strikes the *mulch*[1] soaks through slowly; then, in the entangled soil beneath, it steadily works down to form the underground streams and the springs. Snow in the forests melts slowly and is gradually absorbed in the spongy bed beneath; from this the water slowly escapes into the springs and underground currents. Snow upon the bare ground runs off as fast as it melts.

Actual proof of the difference was furnished a few years ago by an extensive experiment conducted by the United States Geological Survey in the White Mountains. Two similar areas were selected, each covering about five square miles. One of the regions had been entirely cut down and burned over; the other retained the virgin forest (Fig. 224).

[1] The mulch forms a soft, absorbent carpet consisting largely of decaying leaves and other organic matter.

The practical bearing of these facts is not hard to understand. Every year, as the snows on the hills begin to melt, the water rushes down the hillsides in the deforested regions, causing the streams to overflow their banks and the torrents to tear down and destroy everything in their path. The annual damage done by floods in this country is estimated to be equal to one hundred million dollars. This does not include the destruction of human life that is often involved in the floods.

Streams depending upon deforested areas for their water will be too full in the spring and will run too low in the summer. Water used for agricultural purposes must be had in abundance throughout the summer, and the destruction of forests in one region has often resulted in the ruin of agriculture and the migration of peoples in a distant valley. Navigation on the larger streams is influenced by the forest in two ways: the steady flow of water is maintained by a proper condition of the forest, and the filling up of the stream by soil is at the same time prevented.

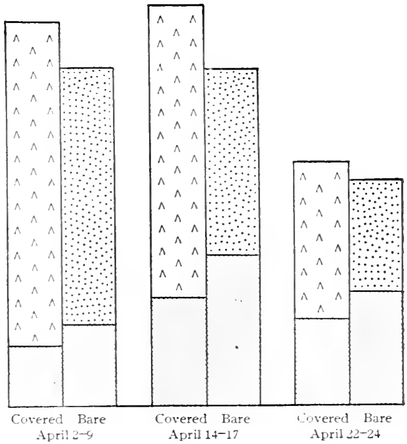


Fig. 224. The relation of the forest to water flow

In experiments made by government agents a comparison of a covered area with one devoid of trees showed (1) that in a given period the covered area accumulated more snow than the bare area (this is shown by the relative heights of the two columns in each pair), and (2) that in a given period the bare area lost more water than the covered area (this is shown by the relative heights of the shaded portions in each pair)

395. Water power. As our industries expand we are pressed to find sources of energy for driving our machines. The consumption of coal has increased so rapidly that the exhaustion of the earth's supply is threatened. Water power seems to be the

only source of energy that is constantly renewing itself at a sufficiently rapid rate; but to maintain the service of waterfalls we must be sure of the steadiness of the water supply, and this in turn depends upon the forest.[1]

396. Soil and forests. Every year the streams and rivers carry down to the sea a quantity of earth estimated to be

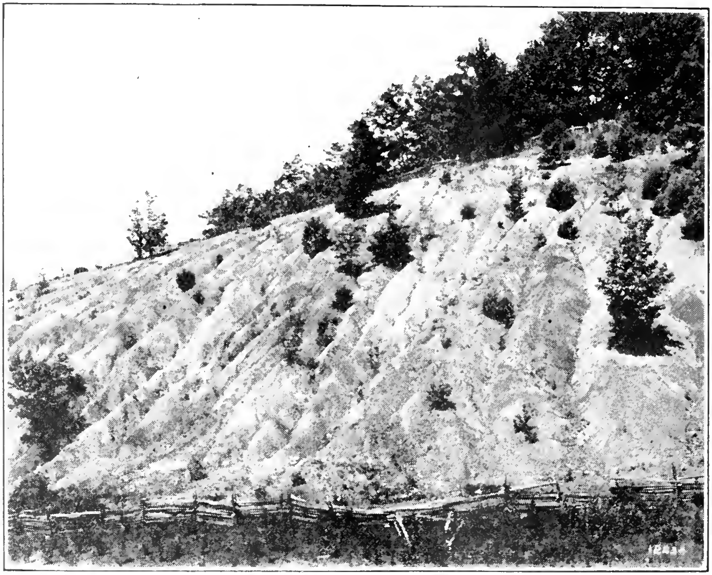


Fig. 225. An eroded slope in western North Carolina

On slopes from which the vegetation has been removed the rains and melting snows produce destructive effects of great practical importance. (From photograph by United States Bureau of Forestry)

worth over a billion dollars. This is not only a direct loss of agricultural resource; it also interferes with the navigation of streams and with the conditions of harbors. Millions of dollars are spent every year dredging harbors in this country, to remove

[1] When we burn coal as fuel, we are of course again dependent upon the forest (though not the forest of our own times), since all coal consists of the modified remains of ancient vegetations.

the soil deposited by the streams coming from deforested regions. And, finally, much of the money and effort spent in reclaiming desert land would be wasted but for supplies of water drawn from regions continually covered with forest.

397. Forest control. Because of our dependence upon the products of the forest, as well as upon the water and the soil that are so much influenced by the living trees, the proper control of the forest becomes a matter of national concern. In the past the private owners of forests could not be depended upon to handle these in such a way as to secure to the general population the full benefits and protection that are necessary. Very often the owner of a forest cares only for what he can get out of it, and he cannot be expected to take into account or feel much concern about effects a hundred miles away or fifty years away.

Fig. 226. A good stand of trees, Lake Placid, New York

Forest areas in good condition not only furnish invaluable materials, but protect the soil and insure a steady supply of water. (From photograph by United States Bureau of Forestry)

The Forest Service of the United States Department of Agriculture, which was established in 1875, has made many careful, scientific studies of forest conditions at the forest experiment stations in different parts of the country. It has thus been able to give sound advice on the care and management of forests and

wood lots from every point of view. From these investigations we learn, first, the importance of avoiding certain injuries to the forests, and, second, the methods of increasing their value.

At the present time the people of this country are using up trees about four and a half times as fast as they are being grown. This means that before very long we shall have destroyed all the usable trees and be

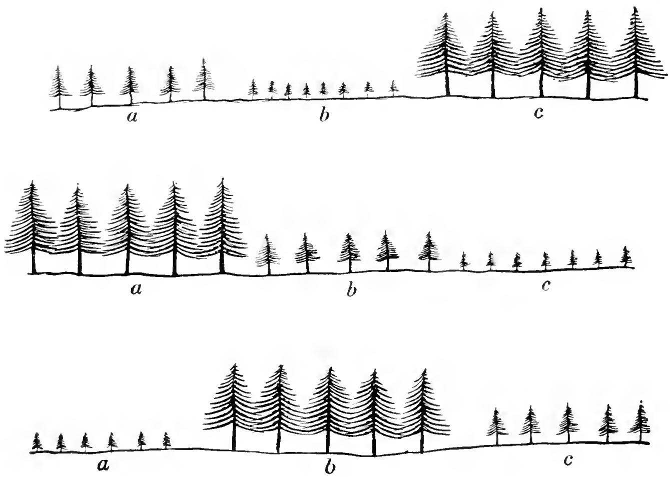


Fig. 227. Cutting trees to preserve forests

The preservation of the forest does not mean simply to avoid cutting timber. By cutting trees in zones at intervals of a number of years, and by thinning out the trees where they are too crowded, it is possible to make a given area yield *continuous* crops of wood. The zone *a* was cut first, then zone *b*, and so on. By the time the last strip has been cut the trees on the first strip are well along, and thus a succession of cuttings may be continued indefinitely

practically without a suitable wood supply. A scientific study of the growth of trees in the forest shows that it is possible to get all the wood we really need without destroying our forest, if only certain principles are followed (Fig. 227).

It is to be noted that the ordinary virgin forest is almost at a standstill so far as growth is concerned. While new growth is constantly taking place, this is only enough to offset the death and destruction among old trees.

398. Increasing forest area. There are over 80,000,000 acres of land left barren by "timber mining" and fires. Such areas may be re-

forested, and this process is under way in many parts of the country. There is a great deal of worn-out agricultural land and sand-dune land that would be well suited to forests. In many cases all that is needed is to protect the young growth from fires. Another method of extending the area of growth is by fuller stocking of existing forest lands. Thus, some trees are found growing so close together that they never become thick enough to be of great value for timber; but in other forests the trees are so far apart that valuable space is allowed to go to waste. By selecting trees suitable for a given region, and starting the young plants rather close together and then thinning out carefully, the amount of timber grown on a given area can be greatly increased.

399. Increasing wood yield. It is likely that not more than from 70 to 100 of the nearly 1000 native species in this country are worth growing from the economic point of view. The red cedar grows very slowly; the white pine or the red oak could be grown in the same soil to great advantage. We could replace the red spruce in New England by the Norway spruce, just as many areas of France denuded by the World War, as well as other European regions, are being restocked with Douglas fir imported from this country. In some localities we may perhaps find foreign trees better suited to our purposes than the native trees. In the course of a number of years the rapid varieties will yield much more timber than the others; but rapid growth is not of itself a deciding factor, for it is necessary to consider the toughness of wood and other qualities. The whitewood, or tulip tree, grows much faster than the oak, but it can never be used as a substitute for the oak.

400. Improving wood quality. Without increasing the actual amount of growth, it is plain that the value of the growth can be increased if the trees do not have curved or twisted trunks or branches. By concentrating the growth in the best trees through thinning out the crooked or twisted ones it is possible to increase the yield of a forest area.

401. Avoiding wood waste. In the national forests the lumbermen are given a practical demonstration of the value of scientific cutting, seeding, reforesting, etc., and also of the economical handling of growth. Damage to trees often results from careless lumbering. The tree that is being cut down is sometimes damaged, and it is sometimes allowed to injure trees that are left standing. When wood was cheap, a great deal from each tree was left to rot on the ground. Now everything that can possibly be used is saved, and the remaining brushwood is

carefully burned, instead of being left under the trees as a constant fire risk. At the Forest Products Laboratory in Madison, Wisconsin, one of the eight forest experiment stations, investigations are constantly being made to find the best methods of utilizing wood and other forest products for various purposes.

402. Advantages of public control. The extent of the national forests may be seen in the map below. In these forests are

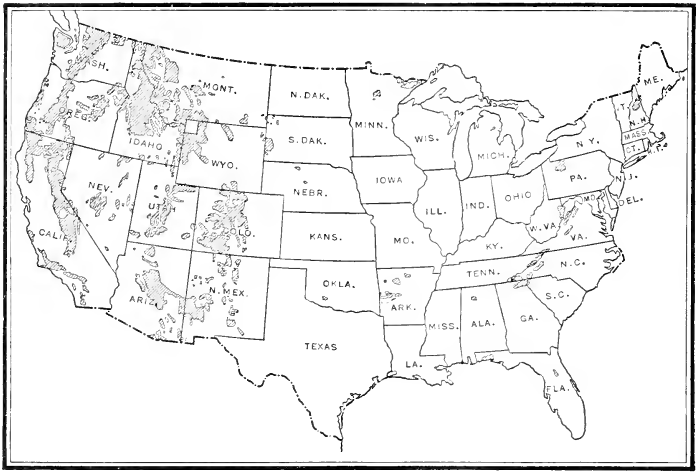


FIG. 228. United States national forests, 156,000,000 acres (1924)

The economy of national control of forests, as well as the protection of public interests thereby, has been strikingly demonstrated

conserved and protected the water supplies for more than a thousand cities and towns, for over twelve hundred irrigation projects, and for over three hundred water-power plants; nearly ten million head of sheep, horses, and cattle graze every year, and nearly half a million people find recreation. The forest service sells timber to private users and gives away firewood to settlers in agricultural lands included within the forest areas.

403. Forest dangers. Four serious dangers menace the forest:

1. The person who cuts recklessly and destroys for immediate profit what ought to last practically forever. This enemy

can be regulated either by enforcing strict rules as to the private uses of forests or by making it impossible for individuals or corporations to profit from the exploitation of forests.

2. Fires, most of which are of artificial origin. Much can be accomplished through suitable regulations and supervision (see table below).

CAUSES OF FOREST FIRES

Records kept by various state foresters and by agents of the United States Forest Service over a period of seven years showed that forest fires averaged over 36,000 a year. The causes were as follows:

	Per Cent
Campers and smokers	15.5
Railroad	14.6
Incendiarism	14.1
Brush-burning	13.5
Lightning	8.7
Lumbering	5.7
Miscellaneous	6.6
Unknown origin	21.3

In the national forests there are well-organized fire patrols. They have succeeded in preventing many fires and in keeping the total fire damage in the national forest down to a small fraction of what it is in privately owned forests. The chief damage done by forest fires is to young growths; this prevents restocking. The rules for fire prevention in forests are posted on trees, and every person who has occasion to go into the woods should heed these regulations.

3. Various species of insects.

4. Various species of fungi. These classes of organisms (insects and fungi) destroy every year trees and timber worth millions of dollars, and there is no one way to fight them all.

404. Other forest relations. The forest is related to human affairs as the home of many animals and of many plants other than the trees. It is in the forest that valuable game and fur animals find their food and shelter, and the destruction of the forest means the extermination of many of these animals.

THE FOREST IN RELATION TO MAN

1. Forest products
   - Wood and its uses
     - Fuel
       - As wood and charcoal
       - As coal
     - Housing, shingles, laths, flooring, etc.
     - Poles, posts, fences
     - Railway ties, cars, platforms
     - Scaffolding, mine timbers
     - Shipbuilding, piers, masts, boats, etc.
     - Packing cases, cooperage
     - Furniture
     - Paper
   - Other tree and wood products
     - Tanning material
     - Pitch; turpentine
     - Rosin; gums
     - (Dyes)
     - (Medical preparations)
     - Sugar and sirup (maple)
     - Distillation products (acetic acid, wood alcohol, acetone, oxalic acid, disinfectants, etc.)
2. Forest and air
   - Relation to oxygen
   - Influence on temperature through transpiration
   - Windbreak
   - Shade
3. Forest and water
   - Retains snows
   - Retards flow of rain water and melting snow
     - Prevents floods in spring
     - Prevents drought in summer
     - Insures water power
     - Protects navigation
       - Equalizes water in streams
       - Prevents deposits of silt
4. Forest and soil
   - Prevents erosion
     - Loss of soil
     - Filling of harbors
   - Makes possible reclamation of desert through irrigation
5. Other forest values
   - Grazing for sheep, horses, and cattle
   - Home for game and fur animals
   - Source of recreation and relaxation
6. Forest dangers
   - Destructive lumbering exploitation
   - Fires
   - Insects
   - Fungi
   - Rodents and grazing animals

7. Forest control
  - Private
    - Working the forest for profit
    - Cannot always consider effects upon remote interests
    - Cannot always consider interests of the future
  - Public
    - Must take into account all interests
      - Water supply
      - Floods and navigation; harbors
      - Soil
      - Future generations
    - Regulation of cutting
      - Selection of trees to be cut
      - Rate of removal
      - Replacement by new plantings
    - Increase of forest area
      - Restocking forests
      - Reforestation of cut or burned areas
      - New plantings on exhausted farm land
      - New plantings on sand dunes and other useless lands
    - Increase of yield
      - More thorough cutting (stumpage)
      - Less wasteful trimming
      - Planting of rapid-growing varieties
      - Protection of growth for better quality of timber

QUESTIONS

1. How can forest conditions in one region influence the interests of people in another region?

2. How can the people whose welfare is affected by what happens in forests in another state protect themselves?

3. What forests influence any conditions in your region? How?

4. What forests are there in your region under private control? state control? national control?

5. What forest products are most commonly used in your region? To what uses are these products chiefly put? Where do they come from? Are there any nearer forests from which the supplies could be obtained?

6. What makes some kinds of trees more valuable than others for furniture? for shipbuilding? for paper-making? for flooring? for barrels? for railroad ties?

7. How does the way in which the boards are cut from the log affect the appearance of the lumber?

8. How are the rings formed by which we commonly tell the age of a tree?

9. How are knots produced in wood? What is the advantage of having knots? What is the disadvantage? How can knots be prevented?

10. What objects made of wood could just as well be made of other materials? What ways are there of saving wood? How can we make sure that the country will never run out of wood?

11. If we found suitable substitutes for wood in its various uses, would the forests be of more importance or less?

12. How can the forests be made to increase our supplies of energy for industry, transportation, heating, etc. without burning the wood?

13. What damage do forest fires do besides burning the trees?

14. How does the amount of timber destroyed by fires compare with the amount cut for use?

15. How is the maintenance of recreation forests like that of city parks? In what ways are these two different?

16. Why should trees be planted in cities? What are the most common street or roadside trees in your community?

17. What lands in your region would be available for forest without loss to farming? When is it better to use land for trees than for agriculture?

REFERENCE READINGS

Moon, F. F. The Book of Forestry.
Linville, H. R. Biology of Man and Other Organisms, pp. 265–276.
Pinchot, Gifford. A Primer of Forestry.
Farmers' Bulletin 1208, Trees for Town and City Streets.
Farmers' Bulletin 1209, Planting and Care of Street Trees.
Farmers' Bulletin 1417, Idle Land and Costly Timber.
United States Department of Agriculture. *Circular 265*, Arbor Day.
United States Department of Agriculture. *Bulletin 863*, Forestry Lessons on Home Woodland; *Bulletin 1241*, How the United States can meet its Present and Future Wood-Pulp Requirements.
United States Department of Agriculture. *Miscellaneous Circular 15*, Importance of Forestry and National Forests.
United States Department of Agriculture. Yearbook for 1922. Reprint 886, Timber — Mine or Crop?
Annual Report of the Forester.

CHAPTER XLIX

INSECTS IN RELATION TO HUMAN WEALTH

Questions. 1. Why have insects caused more damage in this country than in others? 2. Why does the number of insects of a particular species seem to increase suddenly in some years or in some regions? 3. How can we tell whether a particular kind of insect is injurious or harmless? 4. Why cannot all injurious insects be combated in the same way? 5. Are all the injurious insects being killed off? 6. Can an insect be injurious in some ways and useful in other ways?

405. Destructive insects. All kinds of organic matter will serve as food—if not for one organism, then for another. The insects, taking the class as a whole, are fitted to make use of almost anything organic. In this country alone insects of various kinds destroy each year materials and goods estimated to be worth more than two hundred million dollars. This includes stored food, clothing, furniture, carpets and hangings, and furs.

The *clothes moth* is one of the most familiar of these destructive insects, for it is found nearly everywhere that human beings are (Fig. 229). Thorough airing and exposure to sunlight for a few hours will be likely to kill any of the eggs. Naphthalin moth balls do not kill the animals, but repel them and thus prevent destruction. Infested material should be treated with gasoline and then thoroughly aired before being used. To kill the eggs of clothes moths, furniture cleaners and upholsterers sometimes fumigate with carbon disulfid.

The *cockroaches*, of which there are several species, will eat almost any organic matter, but are seldom destructive to valuable materials. Their presence in a house is an indication that there are crumbs and other scraps of food about, and it is perhaps as well for the cockroaches to eat these as for some more objectionable animals to do so. On the other hand, they

may become a serious menace, in the course of their wanderings, since they may carry disease germs to the food.

Ants have been very destructive not only to food materials but also to furniture, clothing, wooden utensils, and even wooden houses (Fig. 230). The Argentine ant was introduced

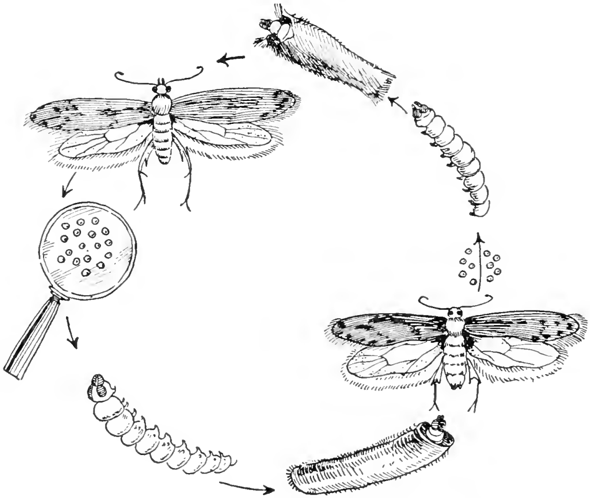


Fig. 229. The clothes moth (*Tinea pellionella*)

It is the larva of this animal that eats woolen and fur material. The eggs are laid on the material and hatch out when the temperature is sufficiently warm. It is for this reason that we rarely find the animals in the winter, and it is for this reason that furs and woolen rugs etc. are placed in cold storage during the summer months. (× 8)

into this country in the early nineties at New Orleans, and has been more destructive in southern parts of the country than any of our native species.

Ants and cockroaches are a nuisance about a house and can be exterminated, once they get in, only through careful attention to their nests, cracks in the walls, etc., and to the availability of material that will attract them. Corrosive sublimate is used to poison them, solutions being sprinkled into the cracks. The cockroaches can be driven out by systematically sprinkling borax about the kitchen.

Weevils, several species of small beetles with beaks, are all very destructive to stored grains, beans, peas, etc. Infested granaries and warehouses need to be thoroughly fumigated with carbon disulfid, which kills the eggs and the larvæ as well as the adults. The cotton weevil is a very serious pest (see Fig. 231).

Flour is often spoiled by other beetles, as the meal-worm (the larva of a black beetle, *Tenebrio* (Fig. 232)), and by a species of moth, *Ephestia kuehniella* (Fig. 233).

The larva of the so-called *buffalo moth*, or carpet beetle, is very destructive to rugs and other woolen material (Fig. 234).

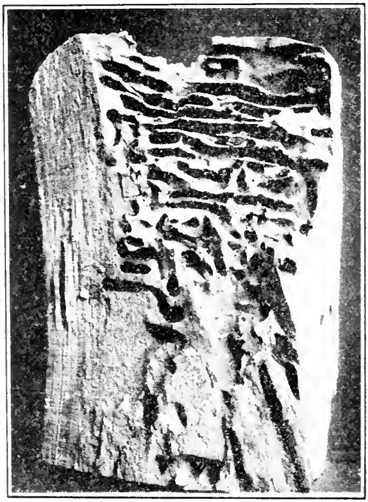


FIG. 230. Destruction by ants

Part of a post completely ruined by the excavations of carpenter ants. There are several species of *Camponotus* and of other genera which are known to bore into wood. (From photograph by New York Botanical Garden)

406. Insects and useful plants. Since men first cultivated plants for their own use, insects of one kind or another have caused parts of each year's work to be wasted. There are early records of the destruction caused by locusts, and this name has come to be applied to many varieties of insects that move in hordes. One of the plagues of Egypt was a swarm of locusts—insects which are repeatedly referred to in the Bible, and which still do much damage.

For fifty years the Federal government and the various states have kept up systematic work through experiment stations and special agents and commissions, designed to counteract the injuries done to valuable plants by insects. It is estimated that the damage done to our crops by the activities of insects amounts to from six hundred million to eight hundred million

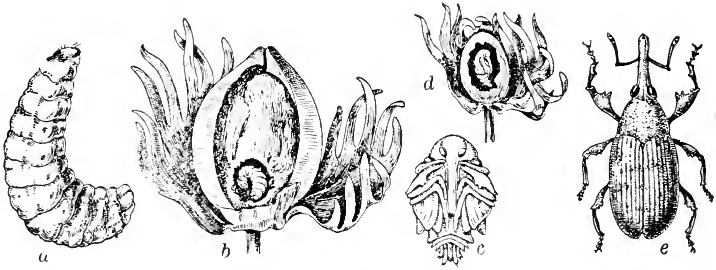


Fig. 231. Cotton-boll weevil (*Anthonomus grandis*). (Greatly enlarged)

This animal feeds only upon the cotton plant and could probably be completely exterminated if the planting of cotton were suspended for a year or two. This was the advice of the government experts to the growers of Texas about twenty years ago; but it was unheeded, with the result that millions of dollars' worth of cotton have been destroyed each year since. Rotation of crops was finally forced upon many of the farmers, with beneficial results. *a*, larva; *b*, larva in mature boll; *c*, pupa; *d*, pupa in boll; *e*, adult

dollars every year. To this must be added the injury to forests and forest products, and the injury to animals.

The locusts and many other species of insects will eat almost every kind of plant; but many insects confine their attention to one or a limited number of food plants. The damage done by such insects is accordingly confined to special kinds of crops.

The *Colorado potato beetle* is perhaps the best known of the special-crop insects (Fig. 235). It is kept in check by the use of poisonous sprays or powders applied to the growing plants.

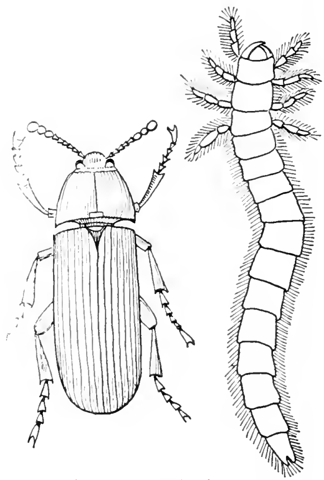


Fig. 232. Meal-worm

Adult and larva of the miller beetle (*Tenebrio molitor*). (× 3)

The *cotton-boll weevil* has spread over a large part of our cotton area in recent years and has ruined many a crop

(Fig. 231). This animal is sensitive to extremes of temperature and has many natural enemies. Planting early-ripening varieties in wide rows, and then burning the stalks and rubbish after the harvest, will do much to keep the pest under control.

The *gypsy moth* (Figs. 236 and 237) has been a pest for nearly two hundred years and was brought to this country after

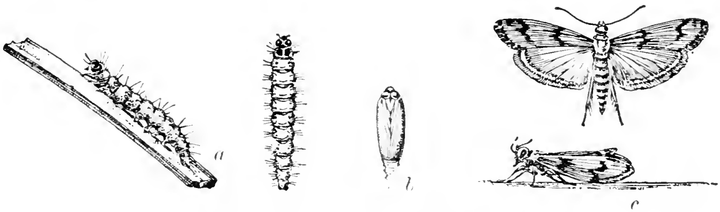


Fig. 233. The flour moth (*Ephestia kuehniella*)

a, larva; *b*, pupa; *c*, adult. (× 2)

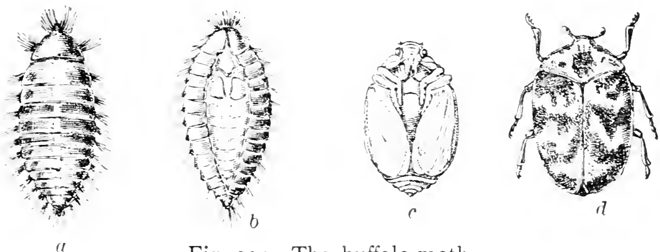


Fig. 234. The buffalo moth

This insect (*Anthrenus scrophulariae*) is a beetle, but is commonly called a moth because it injures furs and rugs in a manner resembling that of the clothes moth. *a*, larva; *b*, pupa in larval skin; *c*, pupa; *d*, adult. (Greatly enlarged)

the Civil War. The larvæ feed upon the foliage of many kinds of forest and orchard trees, ruining the plants completely.

The *codling moth* is familiar to everyone who has found a wormy apple. This insect is present wherever apple trees are grown, and in some regions it destroys from 40 to 75 per cent of the crop (see Fig. 238).

The *Hessian fly* is supposed to have come to this country with the Hessian soldiers during the Revolutionary War. It has spread to all parts of the world, probably attached in the pupal

stage to wheat straw used as packing for merchandise or as bedding for horses and cattle. It has caused great damage to wheat, and it sometimes attacks barley and rye.

The *San Jose* (sǎn hō̍ sā′) *scale* attacks the leaves, twigs, and fruit of many cultivated species of fruit trees. It was introduced from China on some nursery stock and was first noticed at San Jose, California. In twenty years it had spread to all parts of the United States and also into Canada.

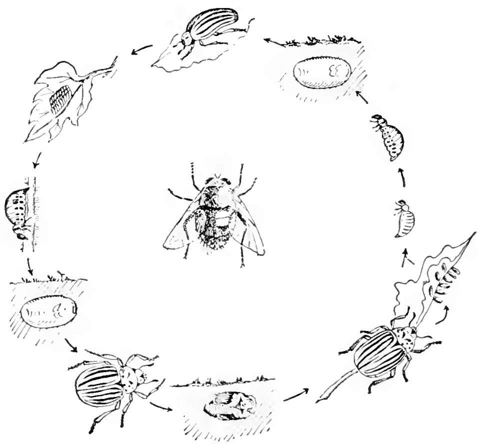


Fig. 235. The potato beetle (*Leptinotarsa decemlineata*). (Slightly reduced)

There are two or three broods a year. The full-grown larva crawls into the ground, where pupation takes place. The winter is passed underground in the adult stage. The tachina fly, shown in the center, is one of the most important enemies of the potato beetle. The fly lays eggs in the larva of the beetle and the maggots destroy their host

Many hundreds of other insects attack our garden and field crops and orchard and forest trees. It is hardly possible to find a plant that has not one or more serious insect enemies.

407. Insects and useful animals. It has been said that every plant and every animal has its parasites and its preying enemies. And it is probably safe to add that every organism of any size has its enemies among the insects.

The mammals and birds that are most familiar to us are annoyed by various flies, lice, gnats, and fleas, which sting and suck blood. Numerous parasitic diseases of animals other than man are transmitted by insects either directly or indirectly, the insects acting as intermediate hosts. In addition, some insects attack larger animals more viciously.

The *botflies* are representative of a large group of insects that are often injurious to horses and cattle (see Fig. 239).

The *ox warble* lays its eggs on the cow. It is not certain whether the larvæ work their way through the skin or from the alimentary canal. They finally lodge under the skin and thus ruin millions of dollars' worth of hides, besides making the animals sick and reducing their milk and beef values.

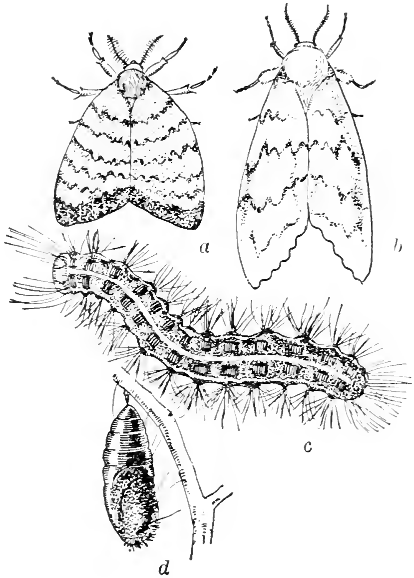


Fig. 236. The gypsy moth (*Porthetria dispar*). (*a*, *b*, *c*, slightly enlarged; *d*, slightly reduced)

This animal was introduced into this country about 1869, in the course of some experiments made to find a substitute for the silk moth, and in twenty years it became so great a nuisance that the legislature of Massachusetts made an appropriation for the study of methods to be used in checking the insect. In ten years over a million dollars was spent in the fight, but further work was stopped by some of the legislators whose regions had not been affected. The insects then multiplied to such an alarming extent that in 1906 about a quarter of a million dollars was again spent in the fight. *a*, male adult; *b*, female; *c*, larva; *d*, pupa

408. Fighting insects. One of the first suggestions that insects could be controlled by encouraging other insects was made about a hundred years ago by two English entomologists, who declared that an increase in the number of ladybirds in greenhouses and fields would clean out the aphids, or plant lice, and insure the hops against destruction (see Fig. 240). These *predacious* beetles do actually devour vast numbers of soft-bodied scale insects and plant lice, which in turn live upon the juices of plants, sometimes causing the destruction of an entire crop.

In this country various species of native ladybirds serve as effective checks upon plant lice of many kinds. It has been possible to control the destructive Hessian fly by means of the parasitic insect *Polygnotus*.

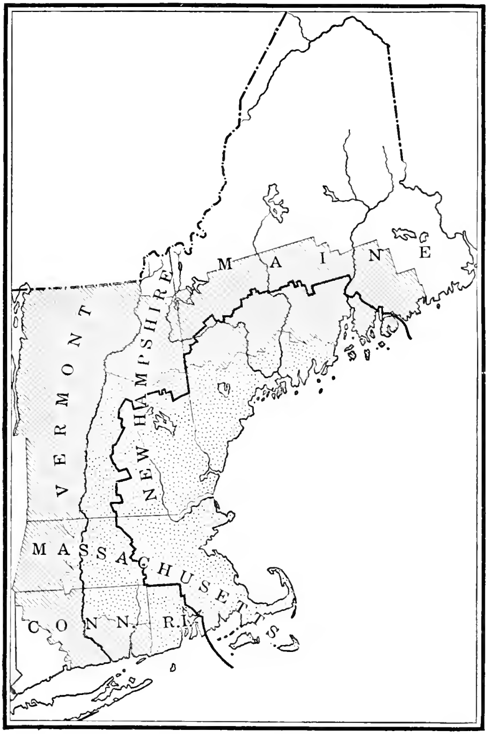


FIG. 237. Gypsy and brown-tailed moths (1924)

Dotted area generally infested and ruled area lightly infested with the gypsy moth. Area between heavy line and the ocean also infested with the brown-tailed moth

Shipments of such parasitic insects from one part of the country to another are frequently made to meet the outbreaks of injurious insects. A further step was taken when specialists were sent abroad by the government to look for natural enemies of injurious insects in the regions from which these insects originally came.

The United States probably suffers more from injurious insects than any other country, because there have come here with the migrations of peoples a large number of foreign insects, without their natural enemies. This country has also done more than any other in the scientific and practical study of insects and of methods of control.

Ladybird beetles have been imported from Australia and Asia to keep down the San Jose scale. Calosoma beetles and several parasitic, wasplike insects have been imported to fight the gypsy moth and the

brown-tailed moth. This kind of work is growing very rapidly. There are now several stations in this country where insects are cultivated on a large scale, to be sent where needed in controlling injurious insects.

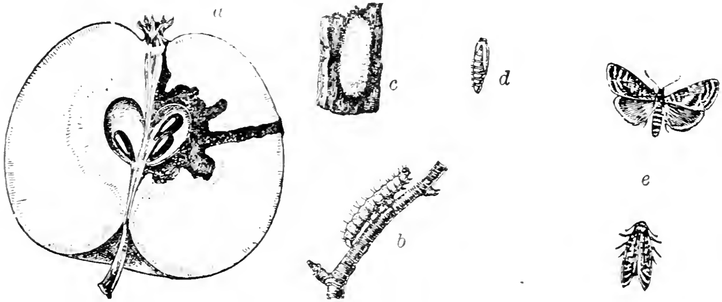


Fig. 238. The codling moth (*Carpocapsa pomonella*)

a, section of apple, showing cavities made by the larva; *b*, larva, the "worm" of the apple; *c*, cocoon; *d*, pupa; *e*, adults. The eggs are laid indifferently all about the twigs. This insect does damage estimated at twenty million dollars a year. (About natural size)

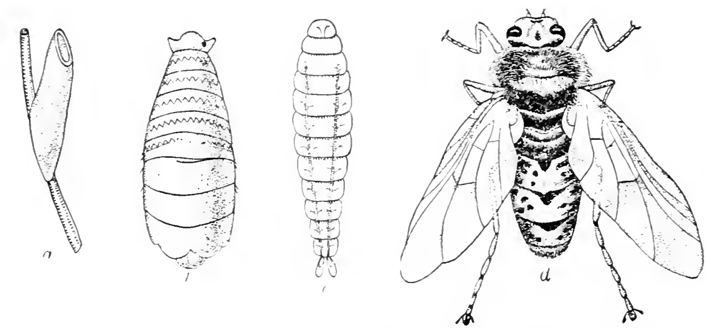


Fig. 239. The horse botfly (*Gastrophilus equi*). (Somewhat enlarged)

The egg, *a*, is laid on the hair of the horse and is swallowed, together with the larva, *b*, in the saliva. In the stomach the larvæ attach themselves, often causing serious irritations and incapacitating the animal for work. The larvæ escape from the host with the excrement, and then pupate in the ground. *c*, pupa; *d*, adult

Spraying of orchard trees, shade trees, and crop plants with various kinds of poisonous mixtures is one of the common means used by farmers to control the damage resulting from insect depredations.

The rotation of crops is used for the purpose of starving out one generation of injurious insects. This can be used against insects that confine themselves to special kinds of food plants.

In recent years it has been found that insects are subject to fatal diseases caused by species of fungi. Cultures of such fungi have accordingly been used to fight insects. A number of the insects are caught alive and infected with the parasitic fungus, and then set free again. The escaped insects infect their fellows, and millions are killed off. This method has been successfully employed against locusts in South Africa and Yucatan.

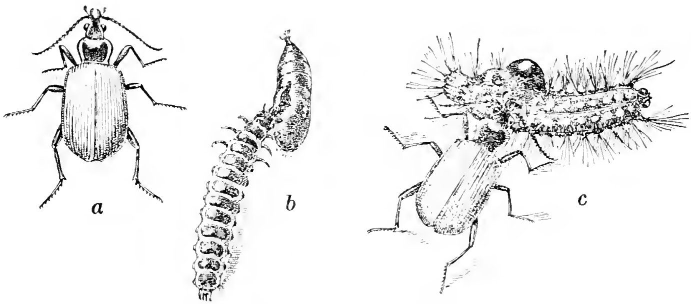


Fig. 240. The calosoma beetle (*Calosoma sycophanta*). (Somewhat reduced)

This beautiful green animal was used by a French scientist in a campaign against the gypsy moth in 1840. In recent years this method of fighting undesirable insects by encouraging the spread of an enemy insect has been rapidly extended, especially in the United States, which leads the world in applied entomology. *a*, adult; *b*, larva feeding on pupa of gypsy moth; *c*, adult feeding on larva (caterpillar) of gypsy moth

The other natural enemies of insects are toads, frogs, snakes, and, most important of all, nearly all kinds of birds. A given amount of money spent in protecting and encouraging the native birds of a region is likely to produce more beneficial results than any other method of fighting insects.

409. The balance of nature. The number of individuals in a species changes from year to year, partly on account of climatic conditions, as when an early frost destroys plants before the seeds are ripened, or when the frost kills off certain enemies. But much of the fluctuation is due directly to the variation in other species. A good year for ladybirds will mean a poor year

for scale lice; but the following year the shortage in scale lice will reduce the number of ladybirds. The living beings are so related to each other that the elimination or unusual increase in one species is likely to affect the well-being or even the existence of another. Every species has its friends in the living world, as well as its enemies, and when man undertakes to change the numbers of any species, he must proceed cautiously and with a thorough knowledge of all the relations of the species concerned, and not merely on the basis of a superficial answer to the question, Is that species useful or harmful to me? It is not a matter of interfering with nature's plans, as some suppose. It is a matter of disturbing a certain *balance* that it has taken a long time to establish, with possibilities of unknown consequences.

When rabbits were introduced into Australia, they multiplied so rapidly that before many years they became a real pest, and the government offered bounties for their extermination. Here was a region admirably fitted for the life of these animals, but until man interfered there had been no such animals there. A similar thing happened with the introduction of the water cress into New Zealand, and with the introduction of the English sparrow into the United States. Probably these organisms throve better in the new surroundings because they did not here meet their old enemies. These facts should help us to realize how closely interdependent the various species of plants and animals are.

INSECTS IN RELATION TO HUMAN WEALTH

1. Insects that destroy organic materials, and how to combat them
    - Clothes moth
        - Exposure to sunlight and fresh air; gasoline; cold storage; carbon-disulfid fumigation
    - Cockroaches and ants
        - Cleanliness about the house; poison with corrosive sublimate; sprinkle borax about
    - Weevils, flour beetle, and flour moth
        - Fumigation with carbon disulfid
    - Buffalo moth
        - Gasoline

2. Insects parasitic on plants

Locust	Tomato worm	Fall webworm
Potato beetle	Tussock moth	Hessian fly
Cotton-boll weevil	Tent caterpillar	Chinch bug
Gypsy moth	Asparagus beetle	Squash bug
Brown-tailed moth	Cucumber beetle	San Jose scale
Codling moth	Cabbage butterfly	Corn borer

3. Insects injurious to animals

(Disease-carrying insects—tsetse fly)	Lice
Botflies	Fleas
Ox warble	

4. Combating insects
   - Use of predatory and parasitic insects
     - Ladybird; calosoma beetle; tachina fly; ichneumon flies
   - Use of parasitic fungi
   - Spraying
     - To control biting insects (beetles, larvæ of moths, etc.)
       - Paris green; acetate of lead; arsenate of lead
     - To control sucking insects (bugs, aphids, flies)
       - Soap solutions; Nicotin solution
       - Lime-sulfur solution; Kerosene emulsion
   - Fumigation of orchards etc.
   - Rotation of crops
   - Burning of stubble etc.
   - Encouraging natural enemies (birds; frogs and toads; snakes; tiger beetles, ground beetles)
5. The balance of nature
   - How change in the numbers of one species may affect other species
     - Increase; decrease
   - Effect of migration or transplantation
     - Favorable; unfavorable
   - Practical importance

QUESTIONS

1. What are the most common injurious insects in your region? What harm do they do?

2. What amount of damage is done by insects in your region to any particular crop or species of plant? to any animals?

3. What amount of damage is done by a particular species of insect?

4. How can insects that are not important in one region be of great injury in another region?

5. How can insects that are harmless in one period become injurious at another time?

6. What kinds of insects do their harmful work in the adult stage? in the larval stage? in every stage?

7. What is the best time to fight a particular kind of insect pest?

8. What is the best time for combating all insect pests?

9. How does spraying kill insects? Why can we not use the same kind of spray mixture on all kinds of plants? against all kinds of insects?

10. How does insect powder kill insects?

11. Under what conditions is rotation of crops a good way to kill off insects? How does rotation of crops do it?

12. How does fall plowing help to combat insect pests?

13. Why is it desirable to give the chickens the run of a plowed field before planting? after planting?

14. What must we know about a new insect pest before we can fight it successfully? How can we find out?

15. What are the chances that man's fight against insects will some day be finished? Why?

REFERENCE READINGS

Farmers' Bulletin 740, House Ants.
Farmers' Bulletin 1037, White Ants as Pests.
Farmers' Bulletin 1101, Argentine Ant as a Household Pest.
Farmers' Bulletin 1346, Carpet Beetles and their Control.
Farmers' Bulletin 1353, Clothes Moths and their Control.
Farmers' Bulletin 801, Mites and Lice.
Farmers' Bulletin 1294, The Corn-borer.
Farmers' Bulletin 1371, Diseases and Insects of Garden Vegetables.
United States Department of Agriculture. *Bulletin 824*, Insect Powder; *Bulletin 1051*, Red-Cedar Chests as Protectors against Moth Damage.
Farmers' Bulletin 1326, Control of the Codling Moth.
United States Department of Agriculture. Yearbook for 1916. Reprint 704, Practical Use of Insect Enemies of Injurious Insects.
Price List 41. Insects (from Superintendent of Documents).

CHAPTER L

BIRDS IN RELATION TO MAN

Questions. **1.** Why do birds migrate? **2.** Do all species of birds migrate? **3.** Do any other animals migrate? **4.** Are all birds useful? **5.** Are some birds useful in one place and harmful in another?

410. The food of birds. Like most animals, birds are important to us chiefly because of the food they eat. But, unlike the feeding of insects, for example, the feeding of birds usually turns out to be of advantage to mankind. Many birds have been convicted of eating fruit in the orchards, and the sharp-shinned hawk has been caught carrying off hens from the barnyard. Nevertheless, a systematic study of the contents of birds' stomachs has shown that most of the food of nearly all the common wild birds consists of insects, the seeds of various undesirable weeds, and field mice, shrews, mice, and other undesirable animals. In other words, with a very few exceptions the common birds are worth more to us alive (as destroyers of insects, vermin, and weeds) than dead (as sources of feathers or food) or as objects of sport (see section 339).

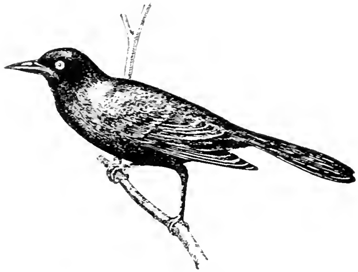
411. Destruction of birds. Many birds are destroyed wantonly by ignorant boys and men, others are killed to supply feathers, and still others are exterminated in the destruction of eggs and nests out of idle curiosity or in the interests of untrained collecting. In rural and suburban districts the domestic cat is a serious menace to the native birds and does far more damage than is paid for by the mice or rats killed; it is doubtful whether we should not all be better off with the domestic cat completely eliminated from our lives.

During their migrations many birds are killed by flying against telephone and telegraph wires, and against plate-glass windows. Along the shores, migrating birds frequently hover

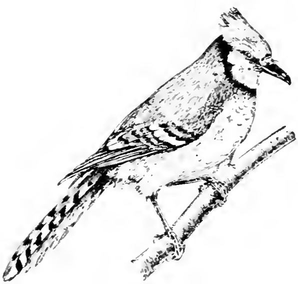
about the lighthouses at night until they are exhausted. The extension of cities, the clearing of forests, and the improvement of farms are all tending to exterminate various species of birds.

The destruction of dead limbs and dead trees in forests and

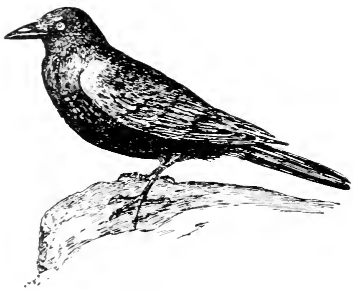
Cooper's hawk (*Accipiter cooperi*)



Bronzed grackle (*Quiscalus quiscula*)



Blue-jay (*Cyanocitta cristata*)



Crow (*Corvus americanus*)

Fig. 241. Some undesirable bird neighbors

Cooper's hawk preys upon poultry and insectivorous birds. The blue-jay and the bronzed grackle destroy the eggs of other birds, and the grackle also eats a great deal of grain. The crow destroys grain, fruit, useful insects, and eggs of useful birds

wood-lots will mean the disappearance of the downy woodpecker and the red-headed woodpecker, but it is worth while to keep the wood-lot clear.

The spraying of orchard trees with poisons intended to destroy caterpillars has led to the death of thousands of birds that

ate the poisoned insects. It is probable that in the long run it would be more economical to encourage the birds to nest in our orchards and *let them keep the insects in check.*

412. Protection and encouragement of birds. Many of the destructive agencies that affect birds are directly under our control. The Royal Society for the Protection of Birds, of England, has had gratings placed upon a number of lighthouses on the coast, to serve as bird-rests. Here the migrating birds rest until morning and then continue their flight. Thousands of birds are thus saved from destruction. When we realize the value of the birds, we shall no doubt plan to build all our lighthouses with some consideration for the safety of these animals, and place electric wires underground, as is now being done in the cities, for example.

Men and boys will have to learn to find sport in opera glasses or the camera; and girls will have to learn to be happy without birds' plumage, or to be content with the dyed feathers of domestic fowl. It is possible to get as much fun out of building nest boxes and shelters for birds as out of shooting or trapping them; and the birds that have been encouraged to make their homes in our immediate neighborhood will continue to furnish us with interesting sights and sounds long after dead birds would have been forgotten. In addition to providing suitable boxes for birds' nests we may scatter grain or bread crumbs after heavy snowfalls and so enable many birds to survive until the ground is clear and they are again able to find food for themselves.

The red squirrel often destroys the eggs and sometimes even the young birds, and does nothing to compensate for this damage. These animals should therefore be killed, to give the birds a better chance. The weasel, the skunk, the fox, the raccoon, and other mammals sometimes kill birds or eat their eggs; but as they do not feed exclusively or largely upon birds, they are not to be considered serious enemies.

413. Undesirable birds. It is impossible to class every species of bird as altogether useful or altogether injurious. A bird

may be very useful in one region and injurious in another. The red-tailed hawk feeds on field mice in one region and discovers that chickens are good to eat in another. The bobolink

Cedar waxwing (*Ampelis cedrorum*)

Yellow-bellied sapsucker (*Sphyrapicus varius*)

Red-headed woodpecker (*Melanerpes erythrocephalus*)

Great blue heron, or crane (*Ardea herodias*)

Fig. 242. Some suspicious tramps

During part of its migration the cedar waxwing destroys fruit and disperses weed seeds; the yellow-bellied sapsucker injures standing trees; the red-headed woodpecker destroys cultivated fruit; the blue heron eats fish and frogs. But on the whole they pay for all they consume, and a little more, and are therefore protected by law

is a serious menace to the rice fields in the South, but is a valuable insect destroyer in the North. The red-winged blackbird ate so much grain in Nebraska a number of years ago that

the farmers took up arms and killed the bird off. The following year, however, the absence of the blackbirds enabled the locusts to multiply so rapidly that many of the grain crops were ruined.

BIRDS IN RELATION TO MAN

1. The food of birds must be studied
   - Observation of bird habits
   - Examination of contents of birds' stomachs
2. Economic importance of birds' eating habits
   - Favorable to man
     - Destroy vast numbers of insects
     - Destroy many rodents
     - Destroy snails
     - Destroy weed seeds
   - Unfavorable to man
     - Eat grain
     - Eat fruit
     - Eat eggs of other birds
     - Eat young of other birds
     - Eat domestic birds (chickens)
     - Eat frogs
3. Dangers to birds
   - Wanton shooting or stoning
   - Unscientific egg collectors (nest robbers)
   - Pothunters
   - Plumage hunters
   - Red squirrels
   - Cats
   - (Skunk; weasel; fox; raccoon)
   - Telegraph wires
   - Lighthouses
   - Disappearance of nesting places by growth of cities, cutting down of trees, etc.
4. Protection of birds
   - Suitable game laws
   - Destroy red squirrels
   - Confine or eliminate cats
   - Provide suitable nesting places
     - Trees
     - Boxes
   - Help over winter (scatter bread crumbs, grains, etc.)
5. Probably undesirable birds
   - Cooper's hawk
   - Grackle
   - Crow
   - Blue-jay
   - Great horned owl
   - Sharp-shinned hawk
   - Pigeon hawk
   - Snowy owl
   - English sparrow
   - Blue heron
6. Suspicious birds
   - Cedar waxwing
   - Sapsucker
   - Red-headed woodpecker
   - Kingfisher
   - Cowbird
   - Starling

QUESTIONS

1. Can you tell from the attractiveness of a bird's appearance whether it is useful or not? from the song?

2. What common birds of your region do you know by name?

3. What birds stay in your region the whole year round?

4. What birds are the first to come in the spring?

5. What ones are the last to leave in the fall?

6. What birds are most common in the summer?

7. What birds pass through without stopping?

8. What common insects do birds help to keep in check in your region? How can you tell?

9. What birds are most helpful in keeping insects in check? How can you tell?

10. What common birds are most helpful in keeping weeds in check? How can you tell?

11. What are the most important dangers to the useful birds in your region? How can these dangers be reduced?

12. What is being done to encourage birds in your community? to protect them? What more needs to be done? Who ought to do it?

13. What harmful birds are there in your region? What harm do they do? How can you tell? What should be done about them?

REFERENCE READINGS

COCKERELL, T. D. A. Zoölogy, chap. xlviii, Birds.
Farmers' Bulletin 513, Fifty Common Birds of Farm and Orchard.
Farmers' Bulletin 630, Birds Useful to the Farmer.
Farmers' Bulletin 493, The English Sparrow as a Pest.
Farmers' Bulletin 621, How to Attract Birds in the Eastern United States.
Farmers' Bulletin 609, How to Build Bird Houses.
Farmers' Bulletin 1239, Community Bird Refuges.
United States Department of Agriculture. Yearbook for 1918. Reprint 785, Federal Protection of Migratory Birds.
United States Department of Agriculture. Circular 261, Purposes of Bird Censuses and How to Make Them.
Price List 39, Birds and Wild Animals (from Superintendent of Documents).

CHAPTER LI

PEOPLE FOR THE EARTH

Questions. **1.** In what ways is the human race improving? **2.** How are improvements in the race brought about? **3.** Why did civilizations die out in the past? **4.** If all the babies were given the same kinds of feeding, treatment, and so on, would they grow up to be more alike? **5.** Are all the children of the same parents alike in every way? **6.** Are the children of educated people more intelligent than the children of ignorant people? **7.** Is insanity inherited? Is criminality? Is alcoholism? **8.** Is it wrong for cousins to marry?

414. Who shall inherit the earth? In every inhabited area the composition of plant life and of animal life is constantly shifting. Some species are increasing and spreading out, others giving way in numbers or moving into new regions. Any existing species may become extinct, as have many species of plants and animals in the past; and any existing species of comparatively little importance may in the future, under special conditions, come to be a great factor in the total life. Man in his wanderings has carried with him his domesticated plants and animals. He has also distributed many of the parasites of his own body and of his cultivated organisms. These movements and migrations may upset the balance of life in a new locality. In some places insects or weeds will take possession and effectively hold the earth against man. The jungle has to be conquered bit by bit. Man is determined to dominate the earth, and he has the capacity to rule. It is by no means certain, however, that the gains of the past will continue, or that what we call civilization will endure forever. We know at least that civilizations in the past rose to great heights and then fell to pieces.

415. Dangers in civilization. The conquest of infectious disease, together with the application of our knowledge regarding

health, resulted in a steady lengthening of human life during the latter part of the nineteenth century and the early part of the twentieth. The average length of life in parts of Europe and in parts of this country has been increased by as much as from ten to over twenty years. In India, where the people refused to adopt modern ideas and modern methods, there was no improvement whatever. There the average length of life has remained at about twenty-four years, whereas in the other countries it has gone up to fifty years or more. Where disease kills a large number of people, those who survive are probably less susceptible, or more resistant, to the particular infections, and we should expect that through natural selection the race would in time come to be immune. We have already seen that, whereas light-skinned races are more immune to some diseases (measles and tuberculosis), the dark-skinned are more immune to others (hookworm disease and malaria).

By saving lives, or postponing deaths, civilization interferes with natural selection. Many people have feared that for this reason civilization must lead to a complete degeneration of the race, until we become quite unfit to live. It is a real danger, for example, if several generations of people have been shielded from infection by measles and the disease is then introduced. There is likely then to be a very high proportion of deaths. While there is a real danger, two things ought to be remembered in this connection:

1. If we can guard against measles or smallpox infection for a few generations, we ought to be able to keep up the protection indefinitely, and even in time exterminate the disease.

2. There is no connection whatever between the fitness to resist a particular infection and other kinds of fitness that have human value.

Many of the greatest men and women who have ever lived were not perfect organisms in the sense of having perfect health. John Milton was blind; Beethoven and Thomas A. Edison became deaf; Robert Louis Stevenson and Keats were consumptives. There have been great writers and artists who were lame or humpbacked. The reason why our

greatest heroes did not die of malaria is that most of them were never exposed to malarial infection. On the other hand, there are millions of people who are immune to one disease or another and who either never amount to anything, so far as the progress of the race is concerned, or who turn out to be very undesirable citizens.

Other dangers developed by civilization and man's attempt to conquer the earth are found in war, poverty, and luxury. The human race is the only species of living thing that is constantly setting one part against another. Now, if fighting were a means of selecting the more desirable individuals for the future of the race (the way track trials select the fastest horses for breeding), we might say that war improves humanity. But the fact is that war works just the other way. It is true that the more successful tribe or nation may replace the conquered. But in modern times what happens is this: the bravest and the ones most ready to sacrifice themselves for the group, and those who are physically the fittest are the ones who go to war, and are killed in great numbers; while the feeble, the timid, the ones who do not care, remain behind and become the parents of the next generation. Instead of selecting toward improvement of the race, war always selects toward a deterioration.

Our conquest of the environment has made possible very great increase in our productivity; but this has gone hand in hand with increasing differences in wealth. The concentration of poverty has meant the demoralization and degradation of millions of people in our country; and, on the other hand, the emphasis upon luxury and idleness and extravagance has been just as demoralizing and weakening to a few of the extremely wealthy. These results are also in the direction of breeding poorer qualities in human beings.

416. The social heritage. As *organisms* the human beings of today are probably very much like those that lived thousands of years ago. There is reason to believe that the brains and abilities of the people who made ancient civilizations in different parts of the world were about the same as our own. Man has learned to preserve the results of experience in customs

and writings and buildings and monuments and in ways of doing things. Each generation may indeed start with a little advantage, but this is an advantage in *environment*, not in *organism*. We cannot talk any better than our ancestors, but we can use motor cycles and aëroplanes, and so get about faster. We cannot figure any better than the best mathematicians of old, but we have not only thousands of tricks that have been gathered through the years, but machinery which enables a rather simple-minded person to get difficult calculations done accurately and quickly. And so with our other abilities; the **social heritage** makes us truly richer and more powerful, but this is not the same as saying that the race itself is more competent in any way.

417. Improving the race. The thought of improving the race is a very old one. Two examples of Greek thought are interesting. The Spartans, who were very warlike, attempted to weed out the incompetents and the weak by exposing infants that were not well-formed or robust, so that only the tougher ones had a chance to grow up. They also provided very severe training for the young people, which only the hardiest could endure or survive. Plato, the greatest mind that Athens produced, and one of the greatest that the race has known, advocated the idea that defective people should not be permitted to have children.

In modern times the whole question of race improvement has taken on great importance for several reasons, and it has given rise to a special branch of science called **eugenics**. This name and this science were founded by Francis Galton about 1875. The word *eugenic* comes from two Greek words, meaning "well born." The study was defined by Galton as that of "agencies under social control that may improve or mar the racial qualities of future generations, either physically or mentally."

418. Why eugenics is important. People are not all alike. Some of the differences are not of any importance—color of hair or eyes, the amount of pigment in the skin, the exact shape of the head or of the nose. Some of the differences are of great importance to the individual but not to the race—taste for one

kind of food or another, sharpness of senses (beyond a certain point), muscular ability, swiftness in running. Still other differences are of great importance to the race or to civilized society—more or less intelligence (especially below certain limits), ability to learn how to coöperate with the rest of the community, ability to do productive work, ability to become an honest citizen, and others. How do these differences show themselves practically? Hundreds of thousands of people are so feeble-minded or so unsteady that they cannot be relied upon to earn their living or to be at large. Some people are so incompetent and so unreliable that they are constantly getting into trouble, or making trouble for others, through committing crime or in some other way. Now it is very likely that many of those who get into trouble or commit crime or are incompetent suffer because they had not the right opportunities to learn better control. And we have to make a distinction between qualities (good or bad) that are developed through neglect or favorable environment—*acquired* characters—and those that appear because the individual comes from a particular strain of germ—*inherited* characters. But it is quite clear that there is a serious proportion of our population that is socially undesirable because of inherited defects or shortcomings.

419. Heredity in man. Heredity works the same in man as it does among other mammals, or indeed among other organisms in general. For a number of characters it has been possible to show that Mendel's principles apply in man as well as in peas or insects. Some of these characters are given in the table on page 585. It is also true for man, as it is for other organisms, that the effects of practice or disease, the effects of changes in the environment, of mutilations, of nutrition, and so on—acquired characters in general—are *not* transmitted to offspring. Studying music will not increase the amount of musical ability in the next generation; musical ability "runs in families," very much as does a peculiar shape of lip or hand. The family of the great musician Johann Sebastian Bach had fine musicians in every generation as far as the records could be obtained. So far as

careful studies of hundreds of family histories can tell us, heredity of mental qualities and emotional tendencies is the same as heredity of physical characters (see Fig. 243). This is what we should expect, since these mental and moral qualities depend so closely upon the structure of the nervous system (including the brain) and the workings of the endocrin glands.

HEREDITY IN MAN

Dominant Character	Recessive Character
Curly hair	Straight hair
Dark hair	Light; red
Beaded hair	Even hair
Brown eyes	Blue eyes
Normal pigmentation	Albinism
Hapsburg lip	Normal lip
Normal muscular tone	Low muscular tone
Nervous temperament	Phlegmatic temperament
Fused fingers or toes	Normal digits
Supernumerary digits	Normal number
Broad fingers (lacking one joint)	Normal length
Limb dwarfing	Normal proportion
Normal growth	General dwarfing

420. Good stock. Someone has said that the most valuable crop in the world is the total of babies born every year. Many of these babies die very soon after they are born (see section 282). With better care more and more are saved every year, yet some people have gone so far as to say that it would be best to leave the babies and the mothers to themselves, so that only those would survive the difficult period who were really fit. There are many babies who could not survive the first few weeks without help, but who would grow up to be very valuable men and women; and, on the other hand, we know that many babies survive very bad conditions, and then turn out to be anything but desirable. Nevertheless a civilized community can do no less than give every baby the fullest opportunity to show what

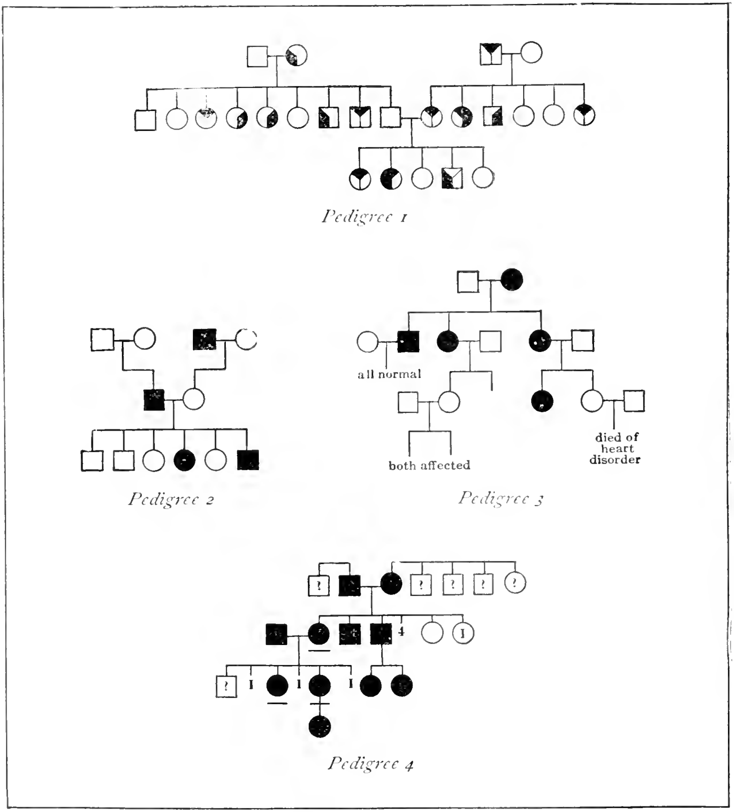


Fig. 243. Heredity of human traits

Squares represent males; circles represent females. *1*, pedigree of a family showing artistic (dark upper portion), literary (right section), and musical (left section) ability; *2*, family with digestive troubles; *3*, family with heart disorders; *4*, family with feeble-mindedness (*I*, died in infancy; *?*, uncertain mental condition). (*1*, *2*, and *3* after Davenport; *4* after Goddard)

is in him, without prejudice about the history or the standing of his family. In this country, perhaps more than in any other, individuals with fine and useful abilities have come from families in the humblest stations.

Valuable combinations of traits persist in families generation after generation. The biographies of distinguished men and women commonly tell something of the family history, and we are impressed with the fact that in most cases the biographer is able to tell of the many good families with which the subject of the story is connected. One of the most remarkable family histories in this country is that of the descendants of Jonathan Edwards, who was president of Princeton College. There were about 1400 persons in this family by the year 1900. They included a dozen college presidents, about 60 physicians and as many college professors, about 100 ministers, about 100 lawyers, 60 authors, 75 officers in the army and navy, and about as many public officials, besides about 30 judges. Jonathan Edwards had four sisters, each one of whom left distinguished descendants, including a signer of the Declaration of Independence, General Ulysses S. Grant, and President Grover Cleveland. In the records of distinguished service to the public certain names appear over and over again, no matter what community history you look into; and certain kinds of talent appear repeatedly. Thus, while the Edwards family gave many scholars and educators, other families gave chiefly prominent scientists or soldiers or statesmen.

421. Poor stock. The records show that certain families furnish excessive proportions of criminals to the community. In very many cases that have been studied, however, shiftlessness, dishonesty, irresponsibility, and other undesirable traits, as well as many undesirable forms of behaving, result from bad conditions of living. Moreover, a very large proportion of those who become criminal and dependent are really feeble-minded and incapable of learning to live in a high-grade manner. Not only, then, is feeble-mindedness inherited, but most children in the families of feeble-minded stock never have a chance to develop their natural abilities for decent living. One of the most striking records is that of the Kallikak family. A young man of good family, during the Revolutionary War, became the father of a child whose mother was feeble-minded. The descendants of

this mating numbered nearly 500 in about one hundred and fifty years. Not one of these was of good ability; 143 of them were feeble-minded. After the war Martin Kallikak settled down and married a normal young woman. The descendants of this couple also numbered about 500 and not one of these was feeble-minded. There are now about 70,000 feeble-minded people in institutions of various kinds; they represent only about a tenth of the actual incompetents who ought to be under control. This means not only that these people fail to support themselves, and so cost the rest of us their keep, but that they cause additional loss through their irresponsible conduct, and often become dangerous to others.

Certain forms of insanity are believed to be inherited, but it is likely that many people who become insane could be saved if they had suitable guidance and environment earlier in life. Much of the crime is also probably preventable through suitable training; yet large proportions of criminals have defective constitutions, that is, hereditary weaknesses of mind or make-up.

422. Uncontrolled population. The advance of civilization, by making it possible for a child or a very simple adult to operate a complex but highly productive machine, has obscured the fact that so many people are incompetent. In fact, it has made it easier for the low-grade people to multiply than for the high-grade. Intelligent young people who are anxious to prepare themselves for high-grade service by continuing their studies are obliged to postpone marriage for several years. Feeble-minded people, who cannot in any case go far in school, usually go to work at an early age; they produce four or five generations of large families in a century, whereas the professional classes produce only three generations of very small families.

If the feeble-minded were in institutions where they would get all suitable care and decent treatment, but no chance to produce offspring, there would be a great saving. It would take a very large amount of money to provide homes or farms for all

these; but in the end that would probably be the cheapest thing to do. After all, they do continue to live, and those of us who are doing useful work have to support them, whether through charity or through taxes or through being robbed indirectly.

423. Controlling the future. The most valuable qualities of mankind are possible only in civilized communities; but civilization brings its dangers to the race. We cannot, on account of these dangers, throw overboard all our gains and return to natural selection. That would only make the beast triumph. The only hope lies in gathering more knowledge and applying it to our practical problems.

The application of our knowledge of heredity to human affairs will probably be along the line of showing us what types of marriages are likely to produce offspring that are undesirable in one way or another. We already know that certain abnormalities of physical structure or of mentality are transmitted in a definite way, and we are therefore warranted in counseling men and women who belong to families that show these characters not to marry others of similar stock. In the course of time we shall no doubt develop certain standards of fitness for marriage which will be enforced largely by the same kind of public opinion and tradition as now distinguishes the customs of different peoples.

In the end the earth will belong to that race which can best use its intelligence to advance civilization and to overcome its dangers—disease, poverty, ignorance, and war.

PEOPLE FOR THE EARTH

1. The earth's population is constantly changing
    - Some species are increasing numerically
    - Some species are diminishing
    - Migrations change the balance of species
    - Migrations carry parasites into new territory
    - Species have died out entirely in the past
    - Mutations give rise to new species
    - Obscure species rise to prominence
2. Man the dominant species of life today—especially civilized man
    - Civilizations in the past have flourished and decayed

- Present civilization carries dangers with it
  - Obstructs natural selection
    - By protecting the feeble against disease
    - By saving incompetence from pauperism and starvation
  - War selects unfavorably by destroying large proportions of the highest types
  - Extremes of poverty and wealth have deteriorating effects
- Offsets to these dangers
  - Physical strength, immunity to special diseases, etc. have no direct connection with human needs in civilization
  - We can use science and skill to guard against disease and so give more desirable types a chance
  - We can use machinery to take the place of mere muscular power and so give opportunity to more sensitive and more delicately organized types of humans
  - We can apply our science to the problem of preventing wars, and so eliminate the unfavorable selection and waste
  - We can apply science to the problems of distribution of wealth as well as to production, and so eliminate degrading forms of poverty
  - We can apply science to problems of education and eliminate the waste and degradation of misuse of our resources

3. Improvement of the race
   - Nothing to show that the race has improved within historic times
   - Greek ideas of race improvement
     - Sparta: reënforce natural selection by rejecting the feeble, sickly, and deformed; severe training and hardship for the young, to weed out those who cannot stand the strain
     - Plato: prevent defectives from reproducing
   - Eugenics (Francis Galton, 1875)
     - Social control of agencies that can improve future generations
     - Why important
       - Individual variation
         - Some traits are more desirable than others
         - Some traits are acquired, but many important ones are inherited
           - Examples of good stock
           - Examples of bad stock
       - Undesirables are multiplying too rapidly
       - Desirable types are handicapped in matters of mere numbers

How eugenics may be promoted
  Control reproduction of feeble-minded and defective
    By placing in institutions
  Encourage high standards of mating among the normal and superior
    Through education
    Through better economic opportunities
Application of principles of heredity to human life

QUESTIONS

1. Are all the capable people in your community free from disease or physical handicap? Are there any sickly people who have fine minds or special talents?

2. What families do you know in which a particular physical trait reappears in two or more generations?

3. What families do you know in which a particular mental trait reappears in two or more generations?

4. Do you know any cases of family resemblances in voice? in handwriting? in peculiar mannerisms? in susceptibility or immunity?

5. Are there any families in your community that have several members distinguished for socially desirable performance or qualities?

6. Are there any families in your community that have several members distinguished for socially undesirable qualities or performances?

7. Have all the capable people in your community the same color of eyes? of hair? the same shape of head? the same complexion? the same stature?

8. Are all the poor people in your community alike in any physical characters?

9. Are all the criminals in your community alike in color of hair? in nationality? in religious beliefs? in political beliefs? in stature?

10. If children are not born more intelligent because of the training their parents received, what advantages have they?

11. Why do most of the children of poor families remain poor?

12. Do the children of wealthy families always remain well off in material things?

13. Are the most capable people always the wealthiest? Are the wealthiest people always the most useful?

14. How do the marriage laws in your state make for race improvement? How can education make for race improvement?

15. How can the good qualities in the population of your community be preserved?

16. What would be the result if we removed the control and restraint of civilized life and returned to natural selection? What classes of people would suffer most? What classes would gain most? What would be the advantages of such return? the disadvantages?

REFERENCE READINGS

Jewett, F. G. The Next Generation, chap. xxvii, Three Steps in Race Improvement; chap. xxviii, Race Regeneration.

Downing, E. R. The Third and Fourth Generation, chap. x, The Practical Problem of Human Heredity.

Linville, H. R. Biology of Man and Other Organisms, chap. xv, Up from Savagery.

Jordan, David Starr. The Human Harvest.

Sumner, W. G. The Forgotten Man (extract in C. H. Ward's "Exploring Nature," pp. 171–178).

INDEX

Marked letters sound as in āle, senāte, ăm, ärm, ȧsk, sofȧ, ēve, ēvent, ĕnd, makẽr, īce, ĭll, ōld, ōbey, ôrb, ŏdd, ūse, ūnite, ûrn, ŭp, fōōd.